JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXV. JANUARY, 1888. No. 1.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

RAPID TRANSIT IN CITIES.

BY PROF. LEWIS M. HAUPT.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 11, 1887.*]

Professor Haupt was introduced by the Secretary of the INSTITUTE, and spoke as follows:—

Number is the basis of comparison. The usual method of expressing the value of an article is by affixing to it a number. Thus, whether the material welfare of a nation be measured by its tonnage, acreage, duties, population, or products, the measure or quantity of each must be expressed numerically. Moreover, it will be conceded that the value of all material products and even of the soil itself, depends upon the existence of man. It is not surprising then, since value is conferred by the presence of man, that population should be made a criterion or measure of material prosperity. Lord Bacon wrote: "The true greatness of a State

consisteth *essentially* in population and the breed of men." That this is true of communities, no less than of nations, does not require to be proven, and hence it is that the prosperity and development of a city are measured by the number of its inhabitants, and that its numerical strength is so jealously guarded.

But there are certain requirements of every community without which it cannot *increase;* it may exist and stagnate, as does a pond of water without inlet, outlet, or internal circulation, but it lacks the vitality of the living stream or lake, and must eventually evaporate.

Intercommunication is, therefore, essential to the development of a city, and the less restraint there is imposed upon a free circulation of mind and matter, the more rapid will be the accretion of knowledge and the increase of population. An acknowledged authority has stated that "rapid transit is the most important single question, no doubt, in any given city."

The fundamental queries before us, are then: What are the obstacles to locomotion in cities, and how may they best be removed or diminished?

The answers are, firstly, that any object which causes a divergence from the straight path joining the terminal points is an obstruction; and, secondly, our physical inability to move ourselves beyond a certain rate of speed, is likewise an impediment. Hence the difficulties in the way of rapid movements from place to place are of a dual nature; the one is external, as pertaining to the path; the other is internal, and inherent in the motor. Both, however, are susceptible of great modification, and the practical problem resolves itself into one of the relation of "the means to the end," or, more plainly, will it pay to make certain proposed modification in the ways of communication?

It will be seen at once, by a brief consideration of the process of development of a community, that the response to this important question is a function of the population, for, in the infancy of a city, when the settlement may have but a few hundred inhabitants, there are very few public improvements which would be justified and these only such as are necessary to support life, as for water, food, clothing, shelter, fuel and light, all of which may for a while be provided by individuals for their own or their families' use. But as the community increases there comes a time when it

is no longer profitable nor expedient for each family thus to provide for itself, and the work is delegated to others, specially appointed. Thus, in brief, the community becomes interdependent and there results an interchange of labor and commodities which must take place over certain channels, more or less direct, and when the population expands to a million or more it becomes a matter of vital importance to increase the facilities for transit correspondingly to prevent engorgement and suffocation from overcrowding, resulting in effeminacy, immorality, degeneracy and ultimate decay. This law is universal, and applies as well to communities as to individuals. If the circulation of a living organism is not maintained it dies. In the same manner if a healthy circulation in a community be impracticable it will lose vitality. The facility of movement when there is but one municipal centre should increase with the population; that is, with the built-up area. As the streets cannot, in general, be shortened, this result must be secured by increasing the velocity of movement. If population is wealth, then it is wise for a city to encourage a heathful growth and provide ready means of access to and from the commercial, manufacturing and financial centres. Hence the question before us is one of almost vital importance for the welfare of our city, and demands our serious and best consideration.

That the method of increasing the rapidity of movement by reducing the distance is the better one, will at once appear by observing that if the distance be diminished, there will result a decrease in time, space and power, cost, wear and tear and risks, while if the desired facility of movement be obtained merely by an increase of velocity, there must be an *increase* of cost, power, wear and tear and risk; the space remaining constant and the time only being reduced.

In a city laid out in squares it is quite possible to reduce the time of transit in certain directions by opening diagonal thoroughfares, and thus not only giving a greater available frontage for building, but bringing a large outlying area within the prescribed time limits.

The distance lost by going around the sides of a square is forty-two per cent. of that by the diagonal, and the waste of time and energy varies in the same ratio, so that our rectangular system of streets is open to serious objection from persons having to

traverse the city diagonally. In 1880, over sixty per cent. of the population lived beyond the limits bounded by Poplar Street, the Schuykill River, and Wharton Street; and the population within these limits had diminished 20,000 in ten years. To-day there are probably over 700,000 persons living beyond the limits mentioned, nearly all of whom, as well as those within the heart of the city, would be directly benefited by such a reduction of distance. The opening of the two main diagonal thoroughfares across this city would reduce the practical distance across by one and one-third miles and effect a saving, which in the aggregate seems almost fabulous.

The street-car travel is now about 125,000,000 per annum. If it cost but a half-cent per mile to transport each passenger, the saving of one mile would represent an annual saving of $625,000, or a capital of $12,500,000. The economy of time to the same number of pedestrians would be 3,565 years, and for those who ride say the half of this, or 1,783 years.

The work done by a man in walking one mile is taken at 33,120 foot-pounds, or about one-fifteenth of a horse-power, so that the energy saved in walking would be 8,333,333 horse-powers per annum.

The figures resulting from a saving of time by *increasing the velocity* are equally surprising when thus taken in the aggregate, as will be seen from the following extracts:

By doubling the velocity it is evident that for a given length of trip one-half the time is saved, so that the round trip requiring one hour, at street-car rate, would take but a half hour at the elevated rate of travel.

Thus a half hour would be saved for each passenger, and for the 125,000,000 this would amount to 62,500,000 hours, or 6,944,444 working days of nine hours.

A SURPRISING ESTIMATE OF WASTE OF TIME.

Taking 300 working days to the year, it would make 23,148 years. Startling as the result seems, it represents the amount of time which is actually sacrificed in this community each year by the *imperfection* of one of our ways of communication.

What is this waste of time worth? Taking the average value of the working day at only $2, it gives $13,888,888. These

figures explain very fully why it is that the public works of a city have so great an influence upon her material welfare.

In those cities which are readily accessible, and where the engineering works are commensurate with the requirements of the community, the increase in population has been very rapid. This is notably the case in many Western cities. In about three years Chicago will have surpassed us in population.

It may be said that such calculations are more curious than useful, but they are intensely practical, and represent facts which are none the less true because not generally observed. It is by recognizing these facts that the prosperity of a community is fostered.

The city also needs to be relieved from the dangerous obstructions and delays, caused by the passage of long lines of freight and passenger trains over and upon the streets at grade. In 1881, I collected the statistics of trains and passengers in and about the city, and found there were 22,000 train crossings per diem, which would amount to twenty per minute in a train day of eighteen hours, or one train upon twenty crossings every minute. This takes no account of the length of the trains, which may cover several crossings at the same time, nor of the rapidity of their movements.

The effect of an increase of velocity upon the available building area is shown by the following statement:

Before the introduction of the street cars in 1858, the built-up portion of Philadelphia covered less than seven square miles, or about five per cent. of its entire area; and during the next quarter century (to 1883) it had increased to but sixteen square miles, or to twelve and one-half per cent. There remained to be developed, therefore, eighty-seven and one half per cent. of the city's limits. The relative areas available, within a limit of half an hour, as affected by the kind and velocity of travel, are theoretically—

For pedestrians moving at the rate of two miles per half hour, 8 square miles.

For horse car moving at the rate of three miles per half hour, 18 square miles.

For elevated railroad moving at the rate of six miles per half hour, 72 square miles.

For underground railroad moving at the rate of ten miles per half hour, 200 square miles.

From this it will be seen that the revenue derived from assessment on real estate, other things being equal, will increase as the square of the velocity of travel.

But in applying these principles to Philadelphia, a reduction must be made for that portion of the salient angle cut off by the Delaware River, and the resulting areas become—

For pedestrians, 6¾ square miles or 5 per cent.

For horse cars, 13½ square miles or 10½ per cent.

For elevated roads, 50 square miles or 44 per cent.

For underground roads, 144 square miles or 112 per cent.

As in 1858, the city covered seven square miles, and in 1883, sixteen, it follows that in both instances it had outgrown the existing facilities of travel. (See *Plate I.*) Although this was proven to be true in 1883, still no material relief has been afforded since, and until it comes the city must relatively decrease in wealth and population. During the last decade the ratio of increase in Philadelphia (including West Philadelphia) was 2·4 per cent., while that of the latter district was 5·9, and of Camden it was 10·8, showing the direction of the movement in population to be along the lines of least resistance.

Marvellous as was the growth of travel in New York in 1884, it has continued rapidly to increase till at present it has outgrown the capacity of the existing plant, and projects are seriously contemplated which would lift the plane of traffic above the roofs of the houses by a series of long-span trusses resting upon tall iron towers, or depress it beneath the surface of the streets; or both methods may be applied as the demands increase. The increase in the elevated railroad traffic for 1887 was over forty per cent., being 158,963,232 passengers.

I have thus attempted to outline briefly the great necessity for, and some of the benefits to be derived from, increasing the facilities of communication, as well as the importance of the subject, and have stated the two general solutions of the problem. Let us now proceed to consider the several elements that enter into the acquisition of such facilities by the second method; viz.:

BY INCREASING THE VELOCITY OF TRAVEL.

At the present day, traffic is usually conducted on the surface, but it may be shifted to an elevated or a depressed plane, and since

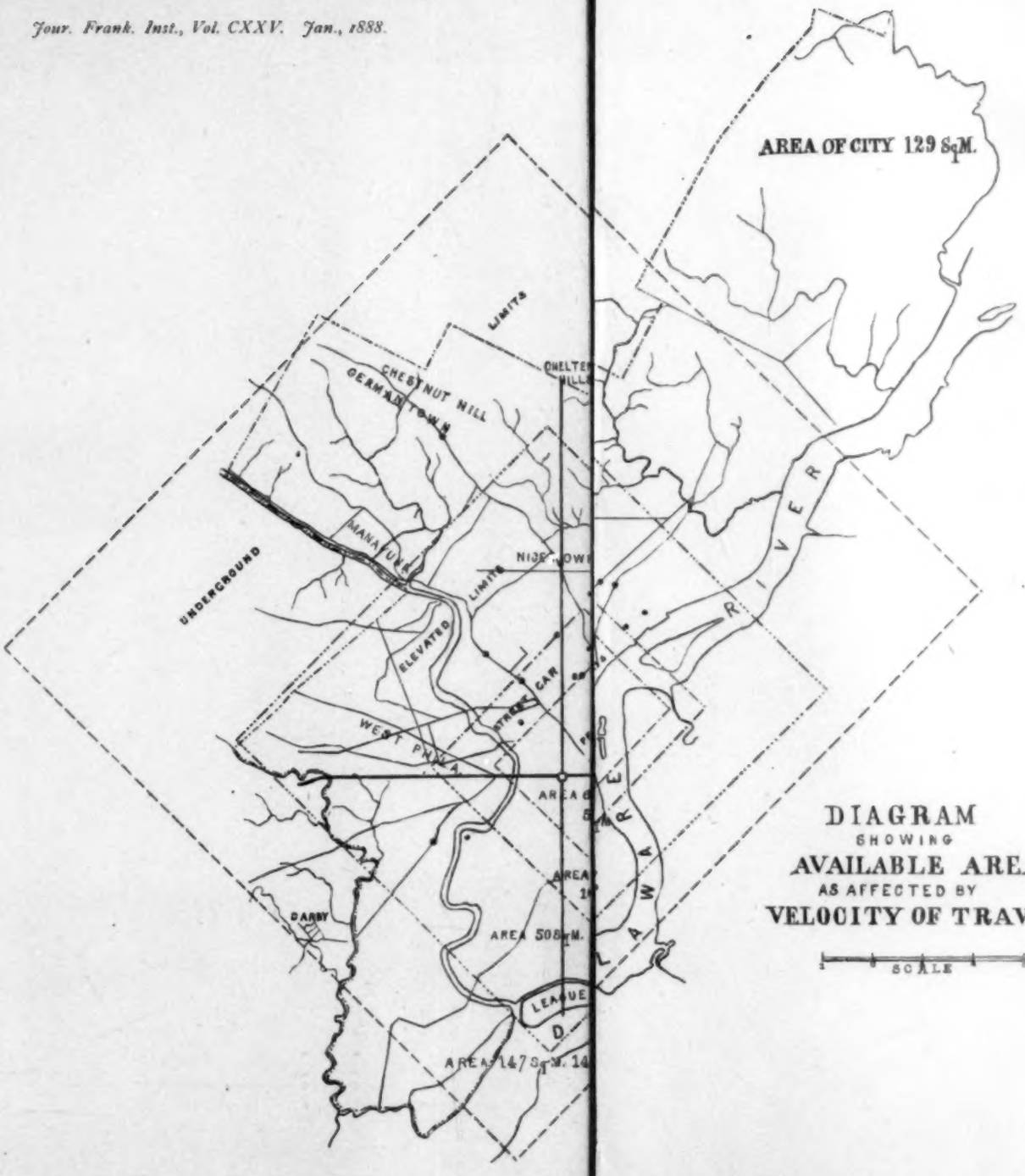


DIAGRAM
SHOWING
AVAILABLE AREAS
AS AFFECTED BY
VELOCITY OF TRAVEL

SCALE mls.

part of map missing

the reasons for removing it from the surface are so manifest, I will merely consider here the relative merits of the elevated *versus* the underground plans.

The elevated structure would be in the air, and at a sufficient height to afford clearance for surface travel, which requires about eighteen feet. In cities it should be made to provide for the passage of extraordinary objects. It would be between the heights of the second and third floors of our buildings; its supports must extend into the streets, and would be something of an obstruction; there would be more noise than at present, less light in the buildings and streets below its grades, dangers from grade crossings of the elevated lines themselves; no relief to present surface travel, so far as concerns the number of vehicles and cars, and the structure could not, without considerable extra cost, be made to possess greater beauty than that arising from its utility and symmetry. Yet, notwithstanding these serious objections, some of which have been reduced to a minimum, if there were nothing else to offer, no city should hesitate to resort to such an expedient when the growth of its population is such as to warrant it. On the other hand, the underground system would pass through the earth, requiring artificial light, ventilation and drainage; its rails should be at twenty feet below the street surface to provide for the ordinary rolling stock of railroads; its patrons would see nothing of the city from the cars, and there would be the same danger from grade crossings as in the case of the elevated roads, but there are the additional direct advantages of less noise to residents, less dirt, no obstruction to light or to traffic of any description. It would furnish a means for relieving the surface of much of its travel; would facilitate the handling of freight; would be more permanent, and cost less to maintain, and would also confer upon the city the incidental benefits arising from having better pavements, requiring less expense to clean and maintain, and avoiding the necessity of continually breaking into them to lay or remove pipes, wires and conduits, which have grown to be so serious a matter. It would give better drainage and provide the sub-ways for all the city service along its route, which no elevated road can do; it would have a velocity sixty-six per cent. greater than that of the elevated road, and hence render about three times as much area available for habitation, within the same time limits; it would have much

greater capacity, both because of its increased velocity and by having four tracks instead of two, and it would pay an indirect annual revenue of great value to the city.

COMPARATIVE COST.

In regard to the relative cost of these two systems, I may say here that we are too apt to jump at conclusions, and to assume that because in general it is cheaper to build in air, than in earth or water, the underground would cost more than the elevated road. If this were the whole statement of the case it would be true, but if we are obliged to compare the cost of construction under the street with that through the second stories of buildings, there can be no question as to which will be the more expensive, and judging from the attitude of our citizens relative to the elevated railway ordinances, the latter condition represents very nearly the sentiment of the majority of the community, whose properties would be injuriously affected by the proposed elevated road.

The projectors of this city would have been more than ordinary mortals had they anticipated the requirements of two centuries, and yet but little departure has since been made in the widths and general plan of the streets, although the demands upon their capacity have enormously increased, and relief is urgently needed. The continual interruptions to travel and business, from the frequent laying of pipes, conduits, sewers, and house connections, are not the least of the inconveniences from which the community suffers. As a matter of municipal economy, it is desirable and expedient that the city should build subways for the better distribution and circulation of those essential elements which go to maintain a prosperous community. These are light, heat, power, water, sewage and sound all of which may be carried as fluids in underground conduits, and be distributed from central stations at much less expense than by the present system.

All things considered, therefore, the creation of a subterranean passage for quick transit of goods and merchandise, with avenues for conduits for fluids and for pneumatic tubes, may possess many and great advantages over the elevated lines.*

However desirable, necessary or beneficial a project may be, if

* The sentiment in New York, as expressed by her papers, is to the effect that *A Subway is the only Resource.*

it is to be carried out by private capital and enterprise, there must be a reasonable assurance of adequate return for the capital and labor invested, and sufficient guarantee that the policy of those authorizing and encouraging the work will remain constant for some definite period of time. In other words, it must appear that the work will pay, and that its projectors will be protected for a limited time from injurious competition.

This principle is recognized as essential to the success of all great undertakings. It was recently stated by one of the eminent judges of this city, that monopolies are evil in principle and become oppressive with age, yet a limited monopoly is essential to protect and encourage new undertakings. Our patent laws, which are based upon this principle, have done very much to develop the welfare of this country by securing to the inventor an absolute monopoly in his invention for a term of sufficient length to protect him from loss. This same principle must be recognized in the efforts now being made to develop the resources of the city by the use of private capital, and it may be plainly asserted that if franchises for the construction of rival lines are to be granted within short intervals of time, it will be many years before rapid transit becomes an accomplished fact in this municipality. Witness New York, where for years three rival companies have been competing and contending for the possession of subway privileges under Broadway.

Coming now to the question of cost and revenue, I will submit a somewhat detailed estimate of the probable expenses and receipts, as obtained from Mr. Jno. J. Deery, C.E., who has given much time to the details of the calculations for the Metropolitan Underground Railway Company, of this city.

ESTIMATED EXPENSES (*per mile*) FOR A FOUR-TRACK SUBWAY SIXTY FEET WIDE.

Earth excavation,	$124,893 00
Masonry in cement,	110,400 00
Concrete (1 : 1),	160,380 00
Bricks, including laying in cement,	103,660 00
Shoring,	30,000 00
I-beams,	135,327 45
Plates and blots,	6,358 08
Sixty-pound steel rails, angles, etc.,	44,136 00
Ties,	2,640 00

Dressed stone masonry,	$24,288 00
Asphalt,	32,313 60
Sewers,	22,000 00
Repaving with Belgian blocks of asphaltum,	34,546 50
Sidewalks,	10,558 80
Electric equipment, locomotive, cars, etc.,	122,000 00
Contingencies and engineering expenses, etc.,	96,350 14
Average cost per mile of covered subway,	$1,059,851 57

For the open-cut work, the estimated cost is $580,774.70.

REVENUES (*as per Estimate of the M. U. Ry. Co.*).

Earnings.—14,850,000 passengers, @ 7 cents,		$1,039,500 00
Section A. Four and one-eighth miles, cost,	$4,372,500 00	
Interest, @ 5%,	$218,625 00	
State tax on gross earnings,	8,316 00	
Operating expenses, sixty per cent.,	623,700 00	
		850,641 00
Balance (from passengers only),		$188,859 00

The estimated earnings are at the rate of $252,000 per mile.

In the matter of revenues it should be remembered that it is the long-distance rider who has the advantage, and that in New York the trains are filled at the terminals, leaving little or no accommodations for transient traffic. Thus the short rider is crowded out. In a city like Philadelphia, where the travel is in four directions instead of two, the proportions of short to long rides would be much greater and the revenues increased accordingly.

ESTIMATED REVENUE.

The receipts are based chiefly in such cases upon the number of passengers and the rate of fare, and it so happens that these elements are not hypothetical, but can be determined with considerable accuracy from experience in similar cases. Taking the case of the horse-car traffic as a basis, we find that during the year 1886, there were 128,185,698 passengers carried over the 329 miles of street railway track. This gives 389,622 passengers per annum to the mile, and furnishes one of the units required for the estimate.

The other elements are the unit of tributary area, unit of population, ratio of population to patronage, ratio of street-car to rapid transit travel, ratio of velocities and the rate of fare.

For the *unit of area* I take a strip one foot wide and one mile long, or *5,280* square feet; for the unit of population, the number of persons inhabiting an area of this size; from these the remaining factors are readily found.

According to the census of 1880, there was in the twenty-one wards composing the continuously built-up part of the city an average of 450 square feet of area* to each inhabitant; hence in a *unit* of area there would be *11·75* persons, which is the *unit of population*.

The width of the tributary area for a street-car line will be found by dividing the entire built-uparea by the total mileage within these limits, or eighteen square miles ÷ by 300, which gives ·06 miles, or only 316 feet, as the full average width of the area tributary to the street-car lines of this city, and it shows how admirably we are provided with this means of travel, and how narrow a strip of territory is required to maintain these lines with their unusually large dividends.

The *total population per lineal mile* for this tributary area is then 316 times 11 (omitting the fraction), or 3,476 persons. As before stated, *the traffic is 125 times the population*, and therefore the *patronage for each mile of street-car line* would be 3,476 times 125 = 434,500 persons per annum.

Comparing this computed result with that given from the statistics, as reported by the various companies, it will be seen that it is about 1·1 per cent. larger. This is then sufficiently close to verify the accuracy of the several elements which enter it as factors. We have yet to determine the relation between street-car and underground traffic as affected by velocity.

As in equal time intervals the areas are proportional to the square of the velocity, and as the average population varies directly as the area throughout the built-up sections; if the velocity of underground travel be twenty miles per hour, or three and one-third times that of surface travel, then the patronage should increase as the square of three and one-third, or be eleven times greater if all used the more rapid trains. As a matter of fact,

* Four hundred and thirty-five is the sanitary limit.

however, only a portion of the population do so ride. To determine this proportion, we may take the statistics from New York travel, for there the ratio of travel to population before the introduction of the elevated roads, was just about the same as in Philadelphia, viz., 125 times. It should be remembered, however, that the velocity is considerably less on the elevated than on the underground roads, and hence any deduction from the former will be below the limits, also, that since the construction of these increased facilities the ratio of travel to population has nearly doubled, being now 232 times. In taking the ratio of surface to elevated travel, therefore, from the New York statistics for last year, we should employ the corresponding ratio of total traffic to population. In 1886, the horse cars carried 210,039,484 passengers, and the elevated roads 115,109,591, making a total of 325,149,075, whilst the population was 1,398,931. The elevated traffic was then one-third of the total, or about eighty-two times the entire population.

Applying this ratio, then, we will have $3{,}476 \times 11 \times 82 = 3{,}135{,}352$ for the estimated number of passengers per mile for the rapid transit lines. That this is about equal to the actual patronage, as determined by experience in other cities, is seen from the subjoined statistics, giving density of traffic on rapid transit lines elsewhere.*

	No. of Passengers Per Mile Per Annum.
Manhattan (N. Y.) whole line (elevated),	3,552,000
Manhattan (N. Y.) Sixth and Third Avenues only,	4,215,000
The Metropolitan Railway, Berlin,	1,360,000
London Underground, Inter-Circle, 10·4 miles, estimated,	8,000,000
Metropolitan London Underground (whole line) 22 miles,	2,879,000
Metropolitan London Underground (District) 13 miles,	2,250,000
North London Underground,	2,680,000
Omitting the Inner Circle (estimated) the average is,	2,822,666
Average of all lines in England and Wales,	52,000
Average of all lines in United States (excluding elevated),	2,854

The entire annual traffic is then over 1,000 times that of ordinary railroad lines. The cost may, therefore, be greatly increased with the same prospect of dividends.

It also appears that the average passenger traffic is, in round

* *Railroad Gazette*, May 6, 1887.

numbers, 3,000,000 per mile, and that it is much higher in America than in Europe.

The second factor is the rate of fare. This on the Manhattan roads, where a five and ten-cent rate prevailed, as is proposed here, averaged, in 1886, 6·46 cents, and taking this as a basis it will give for the *gross receipts from passenger traffic only*, 3,135,350 × ·0646 = $202,543.61, which will represent a capital at five per cent., of $4,050,872.20 per mile. This is nearly four times the estimated cost of the line and it is based upon only one source of revenue. The receipts from rent of subways and from freight traffic, which would be conducted largely at night, would also be very large, so that the result we have reached would seem to guarantee an immediate return upon the capital invested, since there would be no need, as in a pioneer line of railroad, to wait for the population and development of the tributary areas.

It may be well to note here, for comparison, that the stock and bonded indebtedness of the Metropolitan Elevated Railway Company of New York, is stated in *Poor's Railroad Manual*, for 1886, at $34,318,000 or $1,055,000 per mile. The road was first opened for use in 1878 and has about reached the limit of its carrying capacity. The net receipts, in 1885, were forty-two per cent., while the last report of the Metropolitan (underground) Railway of London for the first six months of this year shows net receipts of over sixty per cent., or nearly $900,000.

This, too, in the face of the fact that in London the number of trips per inhabitant is only seventy-six, including all lines, and the rate of fare on the underground was but four cents.

London *Engineering* of February 19, 1875, says:

"In London the underground railroad system has been in operation for eleven years, and so great has been its success, so fully does it meet the requirements of the population, that every year adds to its extension. Opened in 1863, with a section of four and one-half miles, from Bishop's Road to Farringdon Street, it has been considerably extended, until now it has a length of about thirteen miles; while new extensions, costing some $12,000,000, are this year in progress of construction. Many millions of passengers are annually coveyed over these underground tracks, which extend beneath the streets in all directions, uniting the principal centres of trade, intersecting all the great railway lines,

and by the marvellous capacity for traffic, facilitating the enormous transactions of daily business, for which London is so renowned."

To further confirm the foregoing figures and to show that they are below the probable results, I quote further from the London *Railway News* a few statements of observed facts.

From the diagram,* *Plate II* (*Fig. 1.*), "it will be seen that before the Metropolitan (underground) line was opened, the London General Omnibus Company carried about 40,000,000 passengers annually. The average fare was seven cents and the cost to the company six and one-half cents per passenger. There was no marked increase in the business of the company until 1872, when, owing to the competition of the railways and tramways, a reduction in price was made. * * * The average fares by omnibus are now practically the same as by the railway, viz., about four cents. The London General Omnibus Company now carries very nearly as many passengers as the Metropolitan Railway, about 75,000,000 each. In regard to cost, however, there is a great difference, the expense per passenger by omnibus being about three and one-half cents, whilst by the railway the average is only one and one-half cents, although the latter spends $120,000 a year upon its road and contributes $160,000 to the local rates, whilst the omnibus is free from both these charges.

"In spite of the higher cost per passenger the omnibus is, however, able to pay twelve and one-half per cent., to its shareholders, whilst, owing to the enormous cost of the road, the railway company barely obtains a five per cent. rate. * * * On the tramway system, where there has of course been a much greater increase of mileage, the expansion in business has been about 100 per cent. On the tramways the average fare is about three cents, and the cost about two and one-half cents per passenger. In the twenty years from 1864 to 1884, the passenger traffic of the metropolis has increased 470 per cent., while in the same period the population rose only thirty-six per cent."

The sequel to this is that the traffic increases rapidly with additional facilities and without injury to existing tramways, so that an underground road will increase and not diminish the patronage of the existing surface lines. It will therefore be to the interest of the owners of the horse railroads to aid and

* Loaned to the JOURNAL by *Engineering News* of New York. See *Engineering News* of October 15, 1887.

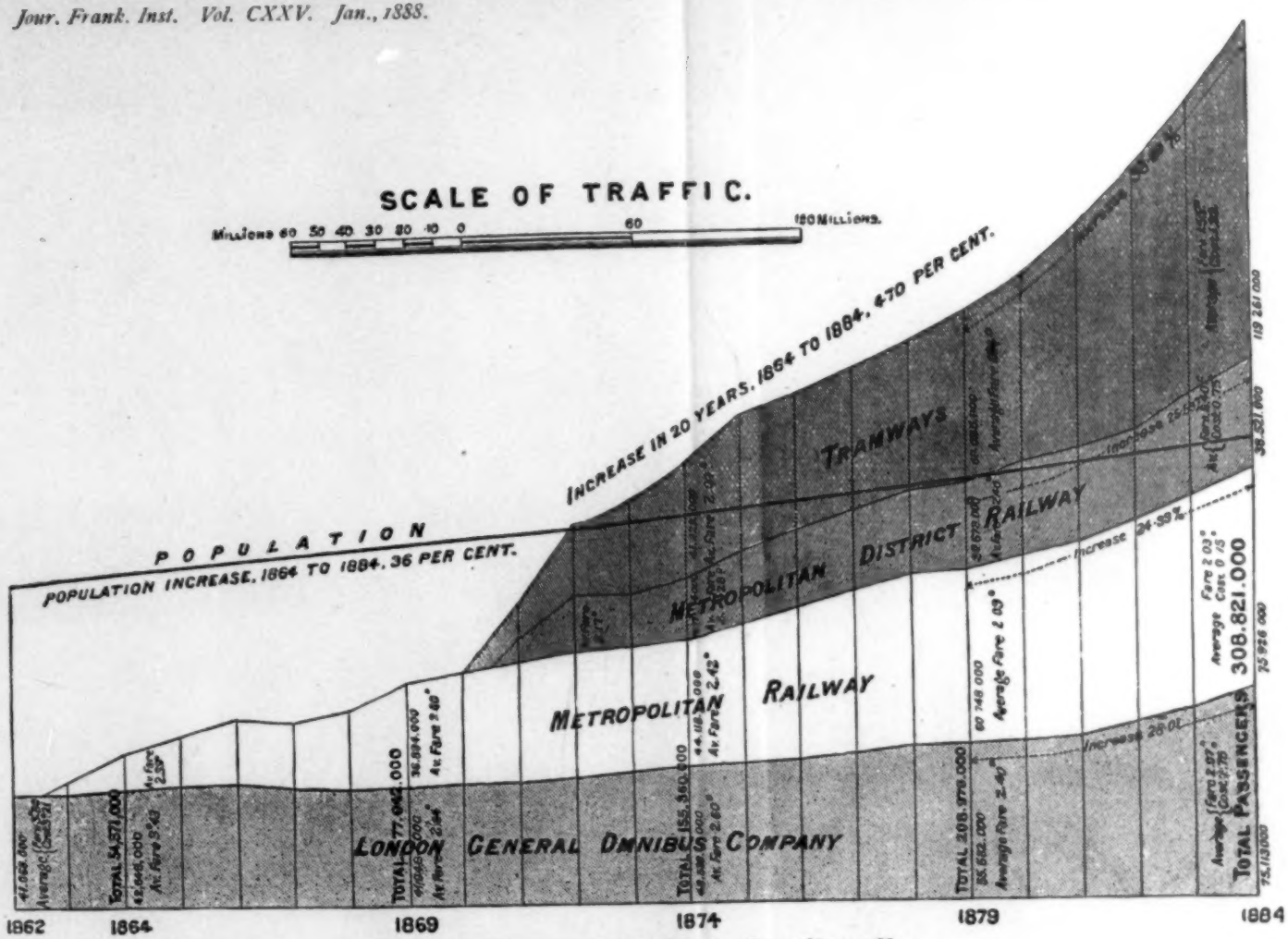


FIG. 1. City Passenger Traffic of London from 1862 to 1884.

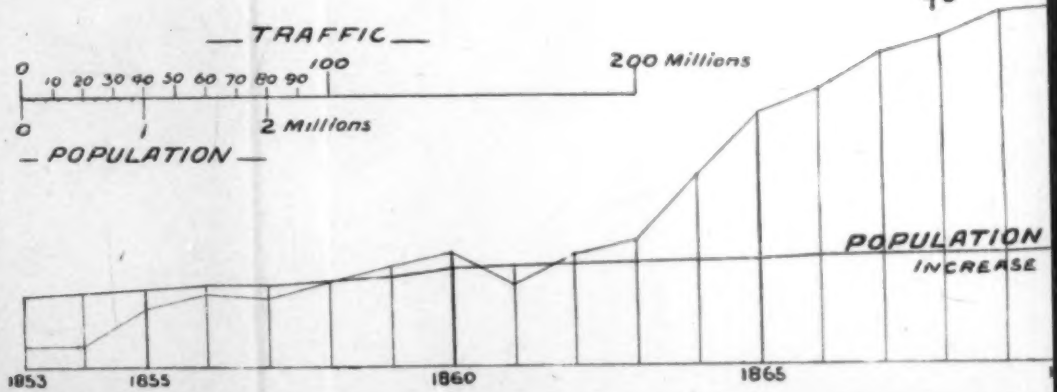
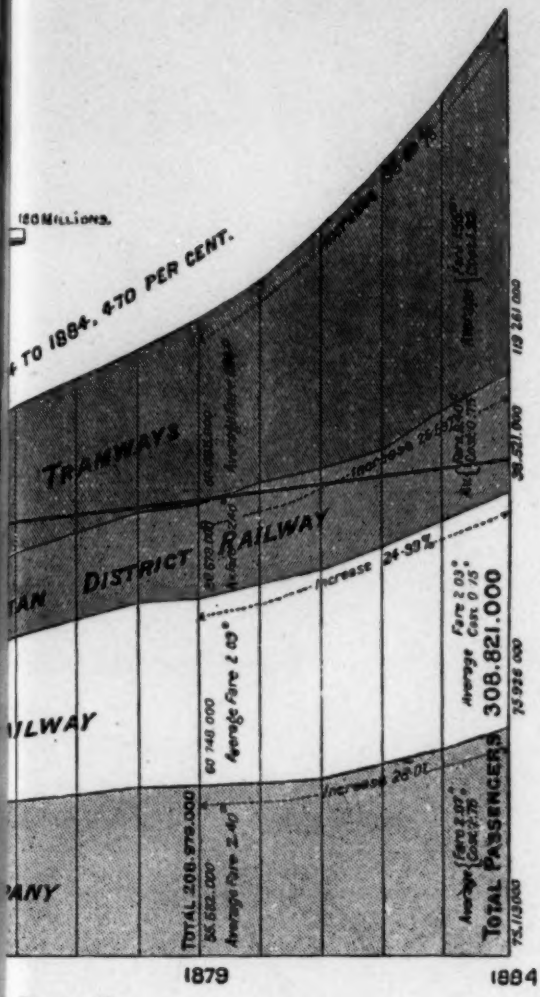


FIG. 2. City Passenger Traffic of



1862 to 1884.

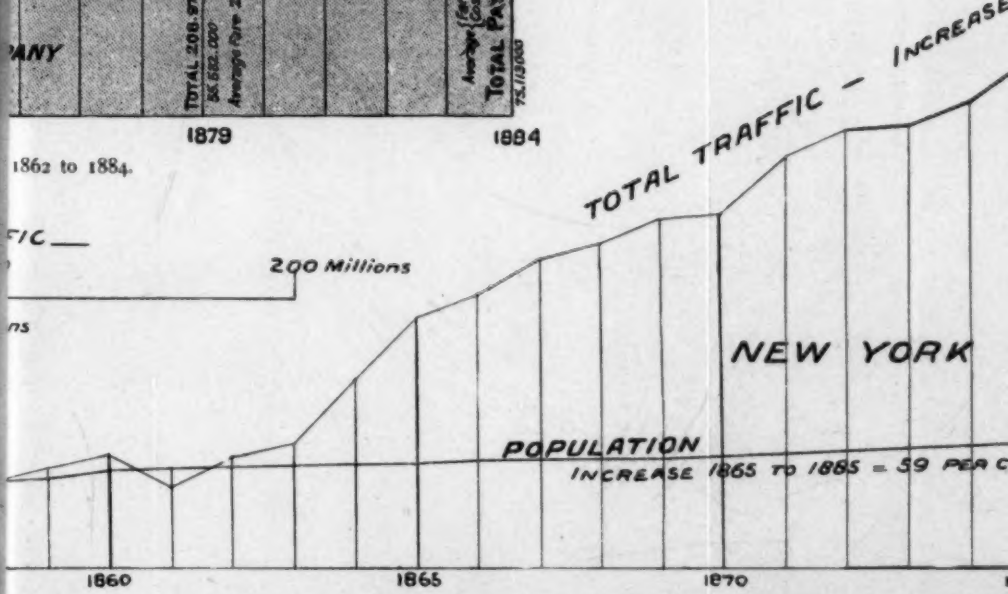
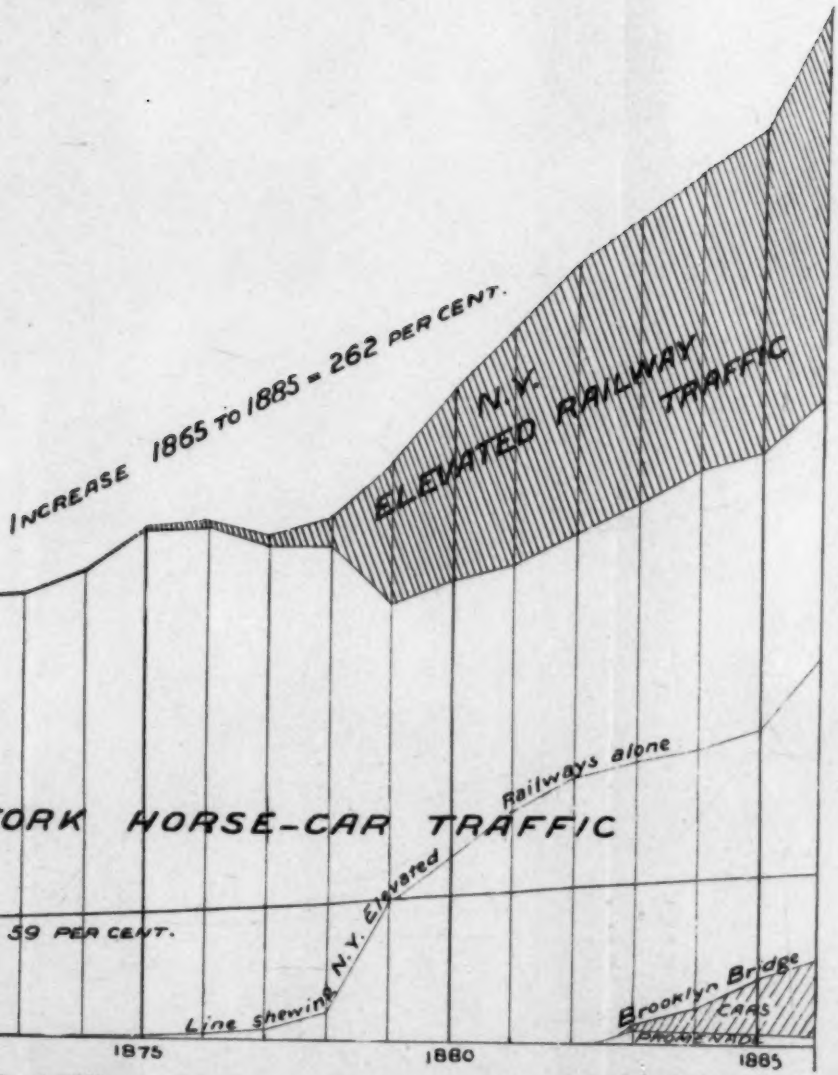


FIG. 2. City Passenger Traffic of New York from 1853 to 1886.


INCREASE 1865 TO 1885 = 262 PER CENT.
N.Y. ELEVATED RAILWAY TRAFFIC
ORK HORSE-CAR TRAFFIC
59 PER CENT.
Railways alone
Line shewing N.Y. Elevated
Brooklyn Bridge
CARS
1875
1880
1885

53 to 1886.

encourage the construction of underground lines, and thereby promote their own interests.

A similar development of traffic in New York is shown on the diagram,* in *Plate II* (*Fig. 2*).

CONFIRMATIONS.

The record of the Berlin Metropolitan Line contains some pertinent facts. For example: It was built by the Government; there was paid for the purchase of property, . . . $8,365,000
and for construction, ... 9,478,000

Total, ... $17,843,000

Less sale of land, not used, ... 1,901,000

$15,942,000

Length, 7·5 miles, cost per mile, ... $2,115,000

It was an elevated masonry arcade. The cost of the right of way was nearly equal to that of the construction—or, deducting the receipts from sales of land, the expenditure for property was very nearly $862,000 per mile.

At the same rate in Philadelphia an elevated road would cost considerably more than one under ground. In an article on "Underground *vs.* Elevated Railroads," the *Railroad Gazette*, of February 18th, says:

"Coming now to the relative economy of construction above and below ground, we shall find that where both constructions have to buy their right of way, the underground would be the cheaper."

As a further check upon the estimate already submitted for the proposed Metropolitan Underground Road, I have looked up the cost of structures already built under nearly the same conditions, and find that the Union Tunnel, built in 1871–73, by the Pennsylvania Railroad Company, under the city of Baltimore, cost $247 per lineal foot, or $1,304,160 per mile. The material was clay, sand and rock. The dimensions were those generally used for double track, viz., 26 feet in width and 19½ in height. The excavation was let at $5 per cubic yard, and the masonry lining at $9 to $9.50. The total length was 3,402 feet and aggregate cost $840,000.

* Loaned by *Engineering News* of New York.

In the case of the underground road, in New York, known as the Fourth Avenue Improvement, provision is made for four tracks, two for express and two for way trains.

The work was authorized May 14, 1872, and the expense was to be divided equally between the city and the Harlem Railroad Company. To this end the city was empowered to raise the money by a special tax on real and personal property. The contract was executed and work was commenced late in the fall of the same year, with the firm of Dillon, Clyde & Co., for the sum of $6,395,070, for the four and one-half miles, or $285 per lineal foot.*

Of the entire distance from Forty-second to One-hundred-and-Thirty-third Street, one section of 6,937½ feet is open cut; one of 4,562½ feet is viaduct, and the remainder, 10,662 feet, tunnelling, or covered way. At the rate of $285 per foot, it would make the cost $1,504,800 per mile. This is for a section seventy-six feet wide in some places, and in which no provision is made for

* The various elements of this estimate are as follows:

	Total Amounts.
Earth excavation and embankment,	$579,000
Rock excavation in open cuts,	701,000
Rock excavation in tunnels,	255,000
Retaining walls,	1,013,000
Parapet walls,	100,000
Foundation walls,	238,400
Granite coping,	134,700
Plank in foundation,	70,000
Piling,	182,000
Concrete,	23,800
Removal of sewer gas water pipe,	300,200
Drain pipe,	6,800
Ballasting,	57,000
Brickwork in arches,	708,500
Blue stone,	34,300
Bridge from Seventy-ninth Street,	334,100
Iron bridges and approaches,	388,000
Wrought iron,	498,500
Cast iron,	23,500
Iron railing,	79,200
Felting,	36,500
Temporary track,	50,000
Ten per cent. for contingencies,	581,370
	$6,395,070

municipal service, and I believe I am correct in saying that no revenue is paid to the city, whereas the section proposed for the underground road here is but forty-eight and one-half feet for the four-track roadway, or about sixty feet, including the sub-ways, and but twenty-four feet for the two-track roadway, or thirty-two to thirty-four feet, including subways.

From these instances, it will be seen how large an amount of money these enterprising corporations felt justified in expending in depressing their tracks to secure the benefits of more rapid movement and less risk in the cities through which they pass. The same policy at this terminal led the Pennsylvania Company* to elevate its tracks along Filbert Street, at a cost of $1,604,480 per mile for the nine track arcade, and it is now proposed to relieve the streets of Jersey City in a similar manner.

We may unquestionably infer then that the city would be amply justified in executing similar works as a part of her municipal improvements for the relief, safety, rapidity of movement and convenience of her citizens; or of aiding in such works by a liberal subsidy which would inspire the confidence of the community and so possibly enable the stock and bonds of the company to be taken at par by popular subscriptions. This would dispense with commissions and discounts, and would to that extent reduce the cost of the work, as well as remove the barrier placed in the path of progress by Senate Bill No. 249.

Such action would not only be expedient, but it would be fully warranted by precedent.

I have dwelt at considerable length upon this matter of "ways and means" rather than upon the the engineering questions involved, because it is fundamental to the success of any movement for the relief of the street traffic and the normal development of our city, and until the populace are satisfied that it is necessary and will pay, there is but little use in considering the mechanical details of the project. These are of secondary importance. It is only necessary to assure the incredulous that there is nothing chimerical or impossible in the engineering or construction

* The cost per lineal foot for the brick arches on Filbert Street, as given by Chief Engineer, Wm. H. Brown, Pennsylvania Railroad, was $266. The roadway is 108 feet wide and accommodates nine tracks.

features, and that the cost of executing them, I believe, would be such as to pay a fair dividend upon the investment.

With reference to the use of an iron superstructure for rapid transit, I beg leave to quote Mr. Wm. H. Brown, Chief Engineer of the Pennsylvania Railroad, to the effect that "there are no iron bridges built at the present time that will last more than ten or fifteen years under the present traffic."

It has now become the settled policy of the Pennsylvania Railroad Company to replace its iron structures by others of stone to reduce expenses of maintenance and increase the life of its bridges. The question of durability is one which has not received sufficient attention in the discussion between elevated and underground roads. To secure it, a masonry arcade on private property, passing through the middle of the block, would ultimately give the best results for an elevated project, but it would no doubt cost more than an underground road and give the city no direct service in subways, and their contingent benefit.

In the limited time remaining we can merely take a superficial view of the various solutions which have been presented for the problem of rapid transit, so far as they relate to the way, leaving out of consideration the rolling stock, motors, expenses of maintenance and operations, and numerous other items.

In conclusion, let us note what amount of territory is required per annum for a normal and healthful growth.

Every person brought into a community requires an average of 435 square feet for his healthful existence. This is at the rate of 100 individuals, or say twenty families to the acre. Deducting thirty per cent. for streets, it would give a lot of a size 18 x 87½ feet per family, which is certainly small enough. If the increase in population be taken at the rate of five per cent., we should have about 50,000 additional citizens a year,* or 10,000 families, requiring 517 acres, or nearly a square mile per year for the immediate future. Unless such an area is provided, a positive injury is imposed upon the individual as well as the community, and as there is no such available room within the already too densely settled built-up limits, the newcomers are obliged to find a habitat on the outskirts, and are subjected to the heavy indirect taxes resulting from loss of time and cost of transportation. This loss of time

* It is now about 20,000.

may soon reach a large percentage of the working day, and will prove in the future a greater barrier to growth than it has in the

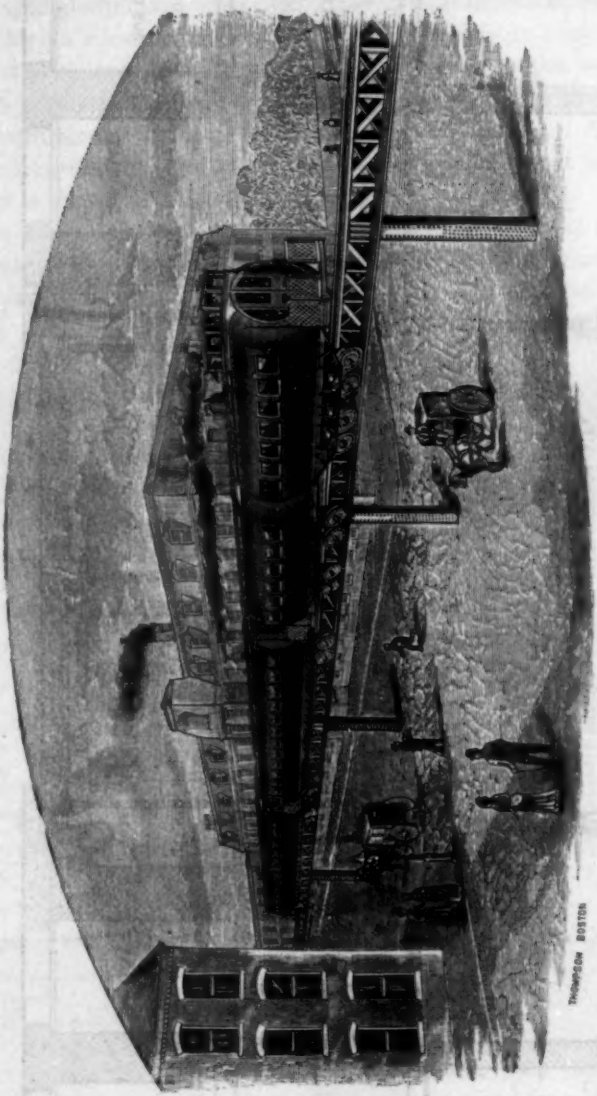
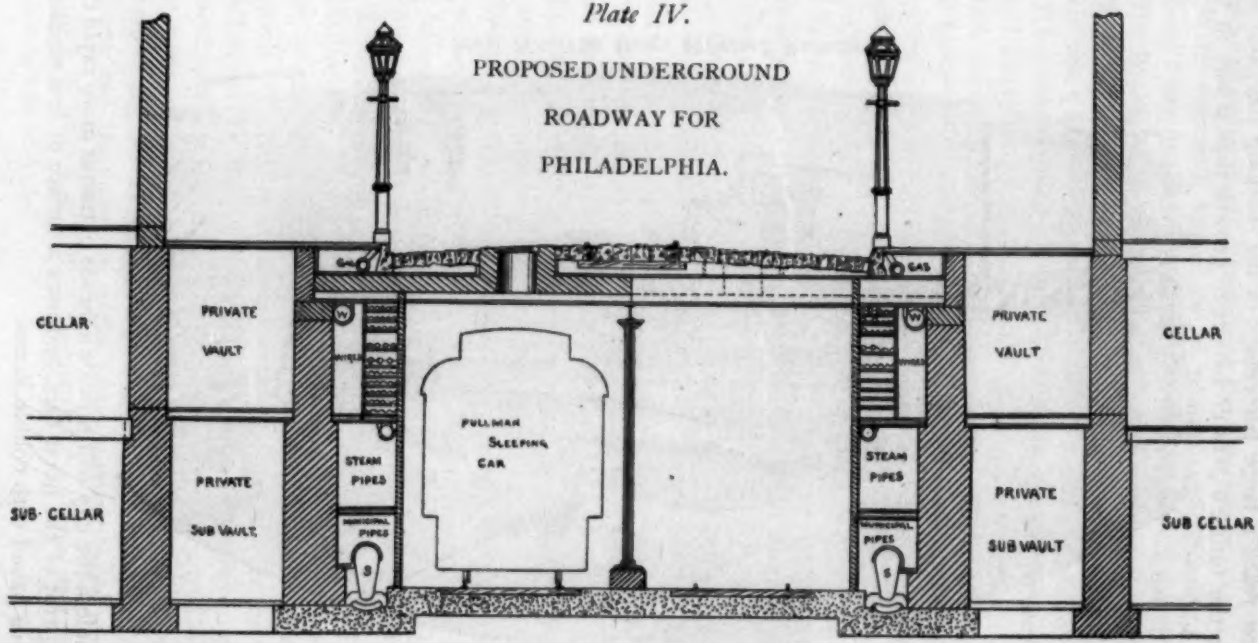


Plate III.—The Meigs Elevated Railway.

past, unless the city will provide a means of transit more rapid than the jog-trot of the horse cars, and over a surface of less resistance than one paved with cobble-stones.

Plate IV.

PROPOSED UNDERGROUND
ROADWAY FOR
PHILADELPHIA.



TRANSVERSE SECTION
ON 50FEET STREETS

NOTE.—The lecture was closed by the exhibition of the typical forms in use for elevated and underground roadways. Amongst these, special attention was called to the radical modifications made in the Meigs' Elevated System, as shown generally in *Plate III*, for which it is claimed that it can be built for $90,000 per mile, and that its trains can be run at a velocity exceeding sixty miles per hour, with almost absolute immunity from derailment. Amongst the underground projects exhibited and described, that for Philadelphia is shown in *Plate IV*.

The accompanying table is appended as a useful guide to determine at what periods a municipality should introduce additional traffic facilities to maintain a normal growth of five per cent.

Year.	City and County.	Percentage of Increase.	Persons to each House.	Built-up Area in Acres.	Area required at 100 to the Acre.	Computed Population compounded at 5 per Cent. per Annum.	Same at 3½ per Cent. per Annum.	Area required at 5 per Cent. Rate at 100 to the Acre.
					acres			acres.
1750	15,000	—	7·1	—	150·00	15,513	12,480	155·13
1760	18,756	25	6·6	—	187·56	25,269	15,974	252·69
1770	*29,444	57	6·5	—	294·44	41,137	20,446	411·37
1780	29,383	(—) ·2	5·3	600	293·83	66,971	26,170	669·71
1790	54,391	85	8·1	—	543·91	109,028	33,497	1090·28
1800	81,009	49	7·2	—	810·09	177,497	42,876	1774·97
1810	111,210	37	6·6	—	1112·10	288,965	54,881	2889·65
1820	135,637	21	6·6	—	1356·37	470,435	70,247	4704·35
1830	188,797	31	6·3	—	1887·97	765,868	89,916	7658·68
1840	258,037	36	4·8	—	2580·37	1,246,833	115,092	12468·33
1850	408,762[1]	58	6·7	2,200	4087·62	2,029,844	147,317	20298·44
1860	565,529	13	6·3	—	5655·29	3,804,586	188,565	33045·86
1870	674,022	19	6·0	—	6740·22	5,379,866	241,363	53798·66
1880	847,170	25	5·2	8,960	8471·70	8,758,421	308,944	87584·21
1890	—	—	—	—	—	14,258,709	395,448	142587·09
1900	—	—	—	—	—	23,213,178	506,173	232131·78
Averages,	—	35	6·3	—	—	—	—	—

* Computed.

1 City and County before consolidation, February 2, 1854.

As a matter of fact the ratio of growth decreases rapidly after the population exceeds half a million, unless rapid transit facilities are introduced.

On Some Early Forms of Electric Furnaces.—

No. 1, Pepys' Electric Furnace.

By Prof. Edwin J. Houston.

The broad idea of utilizing the intense heat produced by powerful electric currents traversing conductors of comparatively high resistance, or of the even higher heat of the voltaic arc, for performing such metallurgical operations as require a high and yet readily regulable temperature, is quite old. The comparative ease with which such heat can be obtained in any required space, as well as the powerful chemical affinities of the terminals of a powerful electric source, led, at quite early dates, to the utilization of electric heat for furnaces. These early furnaces either combined electrical heat with heat of ordinary combustion, or employed the electric heat entirely separate from that of any other source.

The numerous ingenious applications that have recently been made of heat of electric origin, may render a brief reference to the early applications of electric heat to a few furnace operations not without general interest.

We therefore propose giving in successive issues of the Journal a brief notice of a few of the more interesting of these earlier electric furnaces.

When J. G. Children, F.R.S., was experimenting between 1809, and 1815, with his powerful voltaic batteries, he noticed, in common with other investigators, the intense heat he could readily obtain from electric currents.

At a meeting of the Royal Society of London, held on June 15, 1815, he gave an account of an interesting experiment in which Mr. Pepys established the now well known identity of chemical composition of the diamond and ordinary carbon. Pepys' demonstration of this identity was founded on the fact that a diamond, heated in contact with pure iron, under circumstances where admixture with foreign matters was prevented, converted the iron into steel. Such experiments had previously been made, but the certainty of the exclusion of carbonaceous materials, in the opinion of

many, had not been assured. Pepys therefore arranged the experiment in such a manner as to place such exclusion beyond all peradventure. The apparatus devised for this purpose constitutes one of the earliest electric furnaces.

The following description is taken from Vol. 105 of the *Philosophical Transactions* for 1815, p. 370.

"In the year 1796, M. Clouet converted iron into steel, by cementation with the diamond, with the view of confirming the nature of that substance, and of ascertaining the exact state in which carbon exists in steel. Clouet had previously formed steel by cementation with carbonate of lime. Mr. Mushet repeated this experiment, using instead of the carbonate, caustic lime, and obtained also what he considered to be cast steel: whence he concluded that the carbon necessary to cement the iron into steel had not been furnished as Clouet supposed, by decomposition of the carbonic acid, but that it had found its way from the ignited gas of the furnace to the iron. This result occasioned suspicions of the accuracy of the deductions from the experiment with the diamond: and Mr. Mushet accordingly, at the suggestion of the editor of the *Philosophical Magazine*, repeated the experiment made at the Polytechnic school, *only keeping out the diamond*. The results (for he made several experiments) uniformly gave him good cast steel, whence he concludes that we are still without any satisfactory or conclusive proof of the steelification of iron solely by means of the diamond." * * * * * *

"It occurred to Mr. Pepys, that the battery would afford an *experimentum crucis* on the subject: and his ingenuity readily suggested a mode of making it, every way unobjectionable. He bent a wire of pure soft iron, so as to form an angle in the middle, in which part he divided it longitudinally, by a fine saw. In the opening so formed, he placed diamond powder, securing it in its situation by two finer wires, laid above and below it, and kept from shifting, by another small wire, bound firmly and closely around them. All the wires were of pure, soft iron, and the part containing the diamond powder, was enveloped by thin leaves of talc. Thus arranged, the apparatus was placed in the electrical circuit, where it soon became red hot, and was kept so for six minutes. The ignition was so far from intense, that few who witnessed the experiment, expected, I believe, any decided result—On opening the wire,

however, Mr. Pepys found that the whole of the diamond had disappeared: the interior surface of the iron had fused into numerous cavities, notwithstanding the very moderate heat to which it had been exposed; and all that part which had been in contact with the diamond was converted into perfect blistered steel—a portion of it being heated red and plunged into water, became so hard as to resist the file, and to scratch glass."

As will be seen the above is an excellent description of an electric furnace pure and simple. Bearing in mind the date of the publication it shows very considerable ingenuity.

CENTRAL HIGH SCHOOL.

Philadelphia, December 3, 1887.

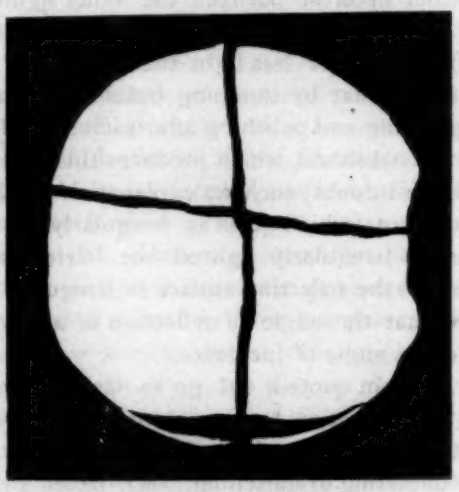
THE JAPANESE MAGIC MIRROR.*

The interesting apparatus, familiarly known by this name, is a circular, metallic, hand-mirror, having figures in relief upon its back. The reflecting surface is highly polished, and reflects the face as well apparently as mirrors of silvered glass; but when it is used to reflect the direct rays of a powerful light upon a screen, the reflection shows, with a moderate degree of distinctness, the figures that are at the back of the mirror. It is a popular belief that the cause of this phenomenon is unknown, and that the Japanese metal workers must have exercised a marvellous degree of ingenuity in the production of such a mirror.

Having recently had an opportunity to examine and experiment with one of these mirrors, I observed that it was slightly convex, and that when it was placed several feet from the eye, objects reflected in it appeared irregularly distorted, as if seen through a bad piece of common window glass. The conclusion arrived at was that there were irregularities in the convexity of the mirror quite sufficient to account for the striking irregular reflection of the sun's rays which is observed. It would be sufficient, in order to reproduce the figures at the back of the mirror, to have its face very slightly less convex on those parts, and such a condition may readily have been produced by means incidental to the quick and economical production of a metallic hand mirror.

* The substance of remarks made at the Stated Meeting of the Institute, held November 16, 1885.

The mirror is thin, the metal very elastic, and the general form of the back is slightly convex, measured by the top of the ornamental relief figures and rim. It is evident that if, in the operation of grinding the face of the mirror, it was held against the grinding surface by a flat support at the back, the pressure would flatten it until the ornamental relief figures rested upon the support, and on those parts the mirror would offer a positive resistance, and be ground away rapidly; but the thin parts between the relief figures having no direct support, would be sprung back by the grinding pressure, and would, therefore, be ground away less rapidly. On removal of pressure, the back of the mirror would



Reflection of Window Bars.

regain its original form, but the face, ground away irregularly, and most where the relief at the back was greatest, would have a slight but irregular convexity greatest on the thin parts between the relief figures.

The Japanese mirror appears to have exactly such a surface as would be produced in this manner. And if so, we should expect that upon springing the mirror flat by pressure, the polished surface would become plane again, and the figures vanish from the reflection. This experiment has been tried, the pressure having been applied by means of a heavy piece of plate glass, with the result anticipated. A photograph of the reflection has also been

compared with the back of the mirror, without discovering any peculiarities that seem to me inconsistent with this explanation. (*See Frontispiece.*)

Sir David Brewster made the first recorded attempt to explain the action of the Japanese mirror, suggesting that the design on the back was reproduced on the face by careful engraving, so lightly done that the figures traced are invisible after the mirror is highly polished, and can be made apparent only by using the mirror to cast a reflection of the direct rays of a powerful light.

Another and favorite theory is that the differences in the surface of the mirror are molecular, the metal having been rendered more dense, either upon or between the relief figures, by hammering, or by a peculiar method of casting, and that the denser parts reflect either more or less light than the rest. An English brass finisher claims that by stamping brass three times with the same die, and grinding and polishing after each stamping, a molecular difference is established, which produces this result. Even if this be true (which I doubt) such an explanation would not apply to the Japanese mirror, which gives an irregularly distorted reflection, as well as an irregularly lighted one. Irregular distortion cannot occur unless the reflecting surface is irregular, because it is a law of nature that the angle of reflection of a ray of light is always equal to the angle of incidence.

One writer, seldom quoted, did go so far as to attribute the irregularity of the reflection to irregularities in the convexity of the mirror, but supposed those irregularities to be due t oa process of stamping, hammering or chiselling. Mr. James Prinseps, in an article in the *Journal of the Asiatic Society*, vol. i, p. 242, makes the following interesting statements:

"The metal is highly sonorous when struck as a bell, and is so soft as to be indented or scratched on contact with any hard surface. I found its composition to be: Copper, eighty parts; tin, twenty parts; with no traces of silver or arsenic, and a very slight indication of zinc."

* * * * * * * * * *

"I believe the true explanation is suggested by the well-known phenomenon of the reflection from a brass button, which every school-boy has remarked when sporting his Sunday 'blue coat with metal buttons' in the sunshine of his tutor's parlor window. The

button throws a radiated irregular image on the wall, exhibiting two bright concentric circles, one on the edge and another about one-third within it, and there is generally a bright spot in the centre; all of this seems but the picture of the stamp on the back of the button; the radii resemble, and, indeed, coincide with, the letters of 'superfine' or 'trebly gilt' inscribed within a double circle, and the central spot represents the shank. There can be little doubt that the principle is in this case precisely that of the Japanese mirror; and, on a cursory view, its surface looks equally smooth and unsuspicious. On a minute examination, however, of several buttons, I found them to be by no means plane; their general surface is slightly convex; there is a hollow in the centre and a projection in the position of the inscription behind, caused no doubt by the blow necessary in stamping it. The polish is probably given by a rotary motion, and consequently does not remove these very small irregularities. To follow up the experimental investigation, I selected one of the buttons which gave a good image, ground it on a flat bone, and polished it; all the magical figures vanished in a moment, and a plain, bright disc appeared in their stead. Here, then, may be a key to the mystery of the mirror; the deception is entirely produced by irregularities in the surface, which are rendered the less perceptible to the eye, because the surface is convex instead of being plane."

* * * * * * * * * *

"It follows from analogy that the thin parts or tympanum of the Japanese mirror are slightly convex with reference to the rest of the reflecting surface, which may have been caused either by the ornamental work being stamped or partially carved with the hammer and chisel on its back, or, what is more probable, that part of this metal was by this stamping rendered harder, so that in polishing it, it was not worn away to the same extent."

The mirror we have here is 9 inches in diameter, ⅛ of an inch thick at the rim, and from ½ to ⅔ as thick between the relief figures. It appears to have been cast and not stamped, hammered or chiselled. It is my belief that it was produced in the simplest manner possible, by casting, grinding and polishing. It is at least certain that such a result, as we have here, must follow such a procedure as I have described, and for the reasons I have stated. Engraving, stamping, hammering and chiselling would be alike

superfluous. It follows, that the magical feature of the first Japanese mirror may not have been, and probably was not, produced intentionally, and that our former estimate of the Japanese metal-workers' ingenuity may be taken *cum grano salis.*

F. E. Ives.

The ETHER-OXYGEN LIME LIGHT.

By F. E. Ives.

[*Read at the Stated Meeting of the* Institute, *Wednesday, December 21, 1887.*]

The vapor of sulphuric ether has been found to give as good results as coal gas in the production of the lime light. As first employed for this purpose, the ether was vaporized by heat, but this method has always been regarded as troublesome and unsafe. Mr. S. Broughton, of England, tried to improve upon it by dividing the oxygen supply and passing a small portion of it through liquid ether, where it became charged with ether vapor, which it then conducted to the hydrogen side of the jet. There were several objections to this method: the oxygen could not be perfectly saturated with ether vapor in this way, and in a cold room or with impure ether there was always danger of the flame retreating into the saturator; if this occurred, it was almost certain to either burst the saturator and throw the burning liquid about the room, or to force it back into the oxygen holder and produce a still more dangerous explosion. The passage of the gas in bubbles through the liquid also caused the light to flicker so badly that I imagine few operators would have tolerated it. Mr. Broughton sought to overcome the first objection by packing the mixing chamber of his jets with granulated pumice, through which the flame will not readily retreat; but this made it almost impossible to use the light at all in two lanterns, connected through a dissolving key, and, of course, did not stop the flickering. Serious accidents resulted from the use of the wash-bottle saturator, and it was abandoned, after creating a general impression that ether could not possibly be employed with safety. Mr. Broughton afterward used a saturator in which the oxygen was passed over the liquid ether instead of through it, and so stopped the flickering,

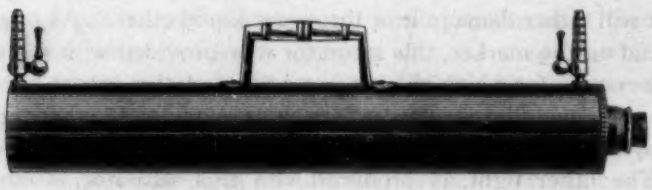
but did not publish this method for some time. The first published improvement on the wash-bottle saturator was invented and patented by me in 1882. It consisted of substituting for the wash bottle a chamber packed with a porous material, which was saturated with the liquid ether and so arranged that the oxygen was charged with vapor without bubbling through the liquid. This saturator was also provided with a removable cap, which permitted the porous filling to be removed and dried out whenever it became overcharged with the alcohol and water that is always present in commercial sulphuric ether. With this saturator, the oxygen can be perfectly saturated with ether, and is then absolutely non-explosive; the light is also perfectly steady, and can be used with perfect success for dissolving, provided that the jets have small tubes and mixing chambers, and the dissolving key a proper adjustment. It is also absolutely safe, if properly connected with the lantern and oxygen supply, because even with an explosive mixture in the saturator, it is impossible to produce an explosion that will either damage it or throw out liquid ether. As originally placed on the market, this saturator was provided with removable rubber caps, for which the present owners of the patent have substituted a metallic screw cap, which is made to fit ether-tight by applying common bar soap to the screw thread.

The ether light, as produced with this saturator, is now employed by some of the best known lantern operators in the country, who are enthusiastic in its praise; but in spite of the success and enthusiasm of many, there are some to-day who affect to believe that its use ought to be prohibited as dangerous, and others who are either too stupid or too "smart" to manage it successfully. Members of the FRANKLIN INSTITUTE have had ocular demonstration of its success and convenience, as it has been used in illustrating most of the INSTITUTE lectures during the past year; but its greatest advantage lies in the extreme compactness and portability of the requisite apparatus. I will take the liberty to reproduce here some endorsements of the light by well-known men who have used it. Prof. Wm. A. Anthony says:

"With the same pressure of oxygen, the ether light is better than the hydrogen. * * * In the qualities of steadiness, freedom from noise, etc., it is certainly equal to any lime light, and in convenience of manipulation, especially for a travelling exhibition, it is far superior to either hydrogen or house gas."

Dr. John Nicol says: "I have been closely identified with lantern work since 1853, and have used and experimented with almost every method of illumination and every variety of apparatus that has been introduced or suggested, and have no hesitation in saying that the production of an oxy-hydrogen light of the very highest class is obtainable with this saturator with absolute safety, and with less trouble than by any other device or apparatus that I have seen."

Notwithstanding the great success of this means for producing the lime light, and the important advantages which it offers, I have always recognized in it certain minor faults, which I hoped to overcome in course of time, and my object in preparing this paper has been to call attention to some recent improvements I have made, which I believe will greatly extend the use of the light, and increase its popularity. The first improvement is in the construction of the saturator, which is reduced in size, yet increased in



effectiveness. The second is in the use of petroleum ether (rhigolene), which gives the same light as sulphuric ether, but vaporizes at a lower temperature, costs much less, and contains neither alcohol nor water to accumulate in the saturator.

My improved saturator is in the form of a single metallic tube, 2 inches in diameter and 13 inches long, with a handle at the middle and a stop-cock projecting upward at each end. A neck, like that of a bottle, projects from the screw cap at the end, and is closed with a cork for convenience in filling. The passage for oxygen is over twenty inches long, in the form of a zig-zag channel through the upper surface of the roll of porous material, and secures complete saturation of the gas with vapor. This saturator can be filled from a bottle in one minute, and is ready for use at once, or may be kept filled for any length of time. It will supply a pair of lanterns, connected by dissolving key, for two hours, continuously.

Petroleum ether costs only thirty cents a pound, which is less than half the price of sulphuric ether. It should be stored in a cool place and kept tightly corked. It is also necessary, when using it with oxygen from a cylinder, to use a valve that can be opened very slowly, because a very small amount of oxygen passing through the saturator will produce a very large flame at the jet; the Shaw valve, manufactured by Mr. Shaw, a member of this INSTITUTE, fulfils the requirements, and is already largely used in this city. Some special instructions for the management of the light in hot weather may also be called for. Upon opening the saturator stop-cock in a warm room, a small amount of ether will vaporize spontaneously, and should be allowed to escape at the jet before turning on the oxygen supply; before the light has been run a minute, the vaporization will have become perfectly regular.

In conclusion, I give it as my opinion that this improved means for supplying the hydrogen element is so much simpler and more convenient than any other, that it cannot fail to entirely supersede the use of hydrogen and coal gas when its merits shall have become generally known and appreciated.

THE REACTION OF A LIQUID JET;

Being a Review of § 522 and § 523 of Weisbach's „ Ingenieur- und Maschinen-Mechanik, Erster Theil; Fünfte verbesserte und vervollständigte Ausgabe, Braunschweig, 1875;"
With some additional matter.

BY PROF. J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

(*Concluded from Vol. cxxiv, page 473.*)

In the first part of § 522 Weisbach states clearly that the phenomenon of reaction concerns the water in the vessel "flowing towards the opening," and he introduces his analysis with the statement: "In the following manner we arrive at a knowledge of the complete reaction of the outflowing water." It ought not to seem inconsistent with this that the analysis itself says nothing about the water in the vessel, but considers it only in the acts of entering and of leaving the same, because quite complicated phenomena are very often governed by such simple and general laws that the complications may be ignored and a result obtained

in a simple manner; besides he does not say "a complete knowledge," but "a knowledge of the complete reaction." But when we consider that the assumption usually made in this problem, that the water enters the vessel in lines parallel with its axis and leaves it parallel to the axis of the jet, is not true in most actual cases and that its motion through the vessel may be a complicated one, it becomes pertinent to inquire how far the equations given apply to such cases and, also, whether the way in which the water flows through the vessel can have any effect on the result. We need, therefore, a *more complete knowledge of the reaction, both completed and incomplete.*

The following considerations will serve to complete our knowledge of the completed reaction. When the water passes through any section, as G, with a velocity not at right angles thereto, such equations as (7) are not true, but become so by putting the component of the velocity perpendicular to the section in place of the velocity itself. Such equations, however, as (5), (9), (11) and (13), expressing the relations between heads, velocities squared and energy, are unaffected by the change if we give a suitable meaning to a; thus in (11), etc., a must be the angle between the velocities c and v. The "2" in the denominator of (19) is a misprint. On the contrary, equations like (7) are not affected by the fact that in actual cases a part of the energy of the flow is continually being dissipated in a vibratory form, as sound, heat, etc., while equations between heads and velocities may require considerable modification on this account.

It has also been assumed that the velocity is constant throughout any section; when it is variable, the whole flow must be divided into elementary streams, for each of which the formula will then apply, and the whole reaction will be had by integrating the differential reactions of these streams or jets. If the elementary streams or jets are not parallel, then to obtain the total reaction in any direction, the components of their reactions in that direction must be integrated. The reaction, then, in any direction of the most complicated jet is simply the momentum per second of the same in the contrary direction.

If we desire a more complete knowledge of the incomplete reactions, *i. e.*, if we wish to know how the water acts before the change from the entering to the issuing jet is complete, including

the effect of a complicated motion within the vessel, we proceed as follows:

When a liquid flows through a pipe of varying section, the velocity of its particles is forced to change, and if the particles move in curved paths centrifugal force is developed; both of these actions affect the pressure on the pipe. The following simple analysis, which I have not, however, seen elsewhere, shows that these actions are in perfect agreement with the principles already developed.*

In *Fig. 9*, $g f$ is an "elementary stream," e and e' are sections of the same and move with it, they are not necessarily at right angles to its axis, but are at a distance apart equal to $v\,d\,t$. The whole stream may be supposed to be divided into elements of this length, in which case each element will, during each interval of time $d\,t$, advance into the exact place previously occupied by the one before it, and will change its length and section correspondingly. The volumes of all such elements will be $q\,d\,t$, and their masses $\delta\,q\,d\,t$, where q is the quantity per second flowing in the elementary stream, and δ the mass per cubic foot, v is the velocity of the element $e\,e'$, and makes with the co-ordinate axes the angles α, β, γ, whose cosines are a, b, c, so that the component velocities in the three directions are $v\,a$, $v\,b$, $v\,c$.

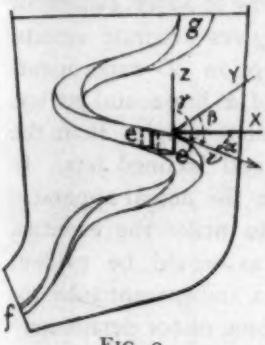


FIG. 9.

It is unnecessary to distinguish between accelerating and centrifugal forces, and we may put at once for the total accelerating force in the x direction

$$X = \Sigma \text{ elementary masses} \times \text{their accelerations}$$

$$= \int_g^f \frac{d\,(v\,a)}{d\,t}\,\delta\,q\,d\,t = \delta\,q\,(v_2 \cos a_2 - v_1 \cos a_1)$$

where a_1 and a_2 are the values of a at g and f_1; we shall have also

*A demonstration for an elementary stream confined to a plane may be found in „Die Physik von Dr. Alb. Mousson. 1879"; elementary streams, however are rarely so confined.

similar formulæ for Y and Z. From these we see that the most complicated motion of the water in the vessel creates only such variations in the pressure of the water as balance themselves on the vessel, thus a whirling motion may cause an equal outward pressure on all sides of the vessel, while it leaves the effect upon the vessel as a whole equal to the difference of momenta per second of the issuing and entering jets, $Q\,E\,D$.

Two models have been designed and constructed by the author for the experimental determination of the reaction of a liquid jet. One of these was intended to give only a rapid approximate measure of the reaction and to be suitable for demonstrating the subject before a class, where a continuous flow of water cannot be had; the other requires such a flow, and gives accurate results. Weisbach concludes § 495 with a description of experiments by Mr. Peter Ewart, in which the reaction of a horizontal jet was weighed; this experiment is, however, much simpler than the measurement of the reaction of vertical and inclined jets. In describing the models, such variations from the actual apparatus will be introduced as may be necessary to make the essential construction more quickly apparent, or as would be evident improvements—such as the substitution of a transparent tube for the tube of brass now in the model—and some minor details may be omitted.

Fig. 10 shows the first model in elevation and plan. It consists of a light glass tube A, 2 inches in diameter and 24 inches long, with brass ends $B\,B$; the upper piece B is a simple flanged collar, while the lower contracts to a nozzle F of $\frac{5}{16}$ of an inch bore. A light vertical shaft C runs the whole length of the tube, and carries a valve D on its lower end; a small rotation of the shaft is enough to slide the valve over the opening F and it is brought to rest in the proper position, and at the same time forced up tight against F by meeting an inclined plane formed by the bent wire E; the spring H tends to close the valve.

To the upper piece B is screwed a piece I which serves to support the different pieces of the upper mechanism. $S\,S$ are two springs hanging from the yoke J and hooked under the ends of I, so that the whole apparatus hangs upon and is weighed by these springs. The yoke J passes through an eye in K, where it rests upon a knife edge, so as to equalize the tension of the springs; a

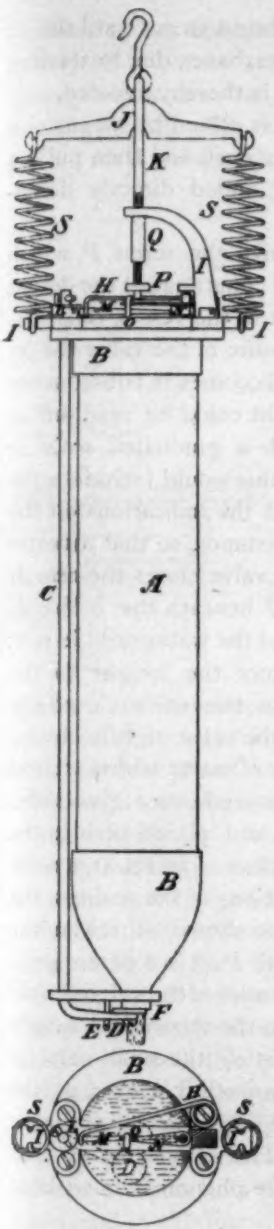


FIG. 10.

hook is also jointed to this eye, by which the apparatus is suspended from a fixed support. The remainder of the mechanism is for the purpose of automatically closing the valve when the flow of water has reduced the weight to a fixed, though adjustable, amount, and is as follows: Upon the top of *C* is a loose collar *L*, having a light arm *M* projecting from it; by means of the pin projecting from its upper surface it engages the pin passing through the top of *C*, and is thus able to close the valve *D* when forced in that direction by the spring *H*; it can, however, be drawn back again into the position shown without re-opening the valve. *N* is a detent revolving about a vertical axis, which receives the end of *M* and holds it in the position shown; the end of this detent being very thin it easily springs down and can be caught behind the hook *O*, against which it rests and thus maintains the parts in the position shown against the pressure of the spring *H*. Its pressure against *O* is, however, extremely small, owing to the reducing leverages of *M* and *N*, and being besides well oiled it requires but the slightest touch to free it, which is done by the adjustable screw *P*. On the lower end of *K*, which is produced below the eye for this purpose, is a nut *Q*, which is so set that when the vessel is nearly filled with water the curved arm of *I* (shown only in the elevation) settles down upon it; were it not for this device the opening of the jet *F* would start the vessel suddenly upward, throwing the springs into vibration; with the nut

properly set, however, the springs do not begin to act until the jet is completely formed, and most of the disturbance due to starting the jet and to starting the vessel upward, is thereby avoided.

When the vessel is filled, the orifice F is closed by means of a cork and the jet is started by loosening the cork and then pulling it out by means of a string fast to it, and pulled directly downwards.

The nut Q is made long enough to receive the screw P, which can be set so that as the vessel rises it will come against the detent N when the water is at any desired height in the vessel, thus disengaging M and closing D. Upon the closure of the valve the jet with its reaction disappears and the vessel becomes in consequence that much heavier; this difference in weight could be read off at once were the instrument constructed with a graduated scale or dial, as is an ordinary spring balance, but this would introduce the question of the accuracy of the springs and the indications on the dial could not be clearly seen from a distance, so that a better method has been devised. As soon as the valve closes the arm M and detent N are reset, and a beaker placed beneath the orifice F, the valve is then loosened just enough to let the water dribble out; as soon as enough has thus escaped to reduce the weight to the exact weight which the vessel had when the valve closed the detent is again automatically released and the valve tightly closed. There will now be in the beaker a quantity of water whose weight equals the reaction of the jet, and this is poured into a glass tube, whose section is double that of the jet, and placed besides the vessel for comparison. If the screw P happens to be set at a point unaffected by the small unavoidable oscillations of the springs, the correct value of the reaction will thus be shown, otherwise the mean of several experiments can be taken with P set in different positions. The height of the water at the first closure of the valve should be marked upon the vessel, and this will be the theoretical height for the water in the measuring tube, neglecting the small velocity of the water in the vessel, friction, etc., inasmuch, however, as the jet has always less than the theoretical velocity, the height after the second closure may be nearer to it. The apparatus, as thus arranged, gives a complete exhibition of the phenomenon without any calculations being needed.

Since the completion of this model I have at various times attempted to obtain an exact automatic register of the reaction throughout substantially the whole period required for the vessel to empty itself. The device last constructed succeeds admirably, and its main points will therefore be described.

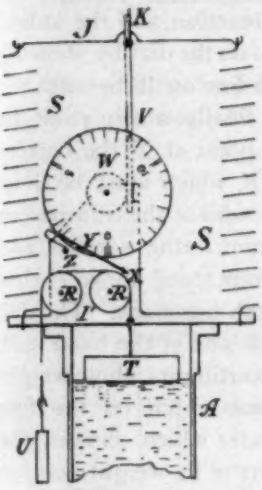


FIG. 11.

Fig. 11 shows a schematic view of the apparatus mounted upon the top of the vessel for registering the reaction. The piece *I* is replaced by another, *I'*, suitable for supporting the different parts of the mechanism, and having also places for the attachment of the springs *S S*; the piece *K* is also replaced by another having a place to attach the end of the rack *V*. This rack engages the toothed wheel *W* fast to the back of the graduated disc, so that this disc is made to revolve as the springs alter in length, and may therefore be regarded as the dial of the spring balance. The disc *W*, rollers *R R* and pen *X Y Z* are all mounted on the piece *I*, and move therefore with the vessel. The rollers support a band of thin tracing paper, eyeletted at the ends so as to connect easily with the float *T* and counterweight *U*, and as the water runs out nearly two feet of this band passes beneath the pen *X*. This pen is exceedingly light, being formed of straw and quill, with a fine wire spring hinge at *Z*, where it is attached to a pin adjustable in a hole in *I*. The pen itself at *X* is perhaps $\frac{1}{8}$ long by $\frac{1}{16}$ of an inch wide, and its handle is a piece split out of a straw about $1\frac{1}{4}$ inches long by $\frac{3}{32}$ of an inch wide. At *Y* a small ivory point is cemented to this straw handle, and the spring is so set as to press this point lightly sideways against *W*, while it also presses the pen *X*, charged with ink, gently down upon the paper band.

Instead of having a spring to close the valve, there is one to open it, either wholly or in part, as desired, and this is set free by burning a thread. The operation of the mechanism must now be evident. As the water flows out, a line is traced upon the band, and in this line slight indentations or notches are made by the graduations upon the revolving disc *W*, which are deep enough to

sufficiently admit the ivory point *Y*. After thus obtaining a register of the heights of the water and corresponding weights of the apparatus, the pen is lifted and the band turned over, and a second register made upon it in the same way, except that the valve is allowed to open just enough to let the water escape quickly in a horizontal sheet; there is then no vertical reaction, and the indentations serve to standardize the graduations on the dial by showing the height of water necessary to bring each line on *W* beneath the ivory point when the valve is closed. If, finally, a zero point be marked upon the band, such that with this point at *X*, the bottom of the float would be even with the orifice *F*, which must be done by measurement, we shall have on the two sides of the transparent band a series of distances from the zero point to the notches, and each distance will be the height at which water stood above *F*, that is, the "head" above *F*, at the time the notch was made. The distance to any particular notch on the second side of the band will, however, be a height of water which was exerting its whole weight upon the spring, and the distance to the same notch on the first side will indicate that greater height of water which showed the same weight on the dial, because only a part of its weight was felt by the springs, the remainder being sustained by the reaction of the jet. In order to distinguish the different lines on *W* from each other, and to make the notches show this distinction, some of the lines are triple and others double.

To get results free from the not-easily-avoidable oscillations of the springs, the distances on the first side are plotted horizontally upon cross-section paper as abscissas measured from a point *F*, representing, therefore, zero height, and so appropriately marked with the same letter as the orifice, and the corresponding distances on the second side are set off vertically as ordinates. If now a right line be drawn as nearly as possible through the points, it should, neglecting the consideration of friction and other refinements, pass through *F* and make an angle with the horizontal whose tangent is the cross-section of the vessel minus twice that of the jet and the difference divided by the cross-section of the vessel, or about sixteen-seventeenths for this model in which the jet is 0·32 and the vessel 1·86 inches in diameter. The value of the tangent is also seen to be $a \div p$ in *Fig. 12*, which shows a piece of the

paper band full size, five inches being cut out to bring the zero point *F* within the limits of the cut.

FIG. 12.

The results obtained from this apparatus are quite accurate and agree with those calculated by the formula.

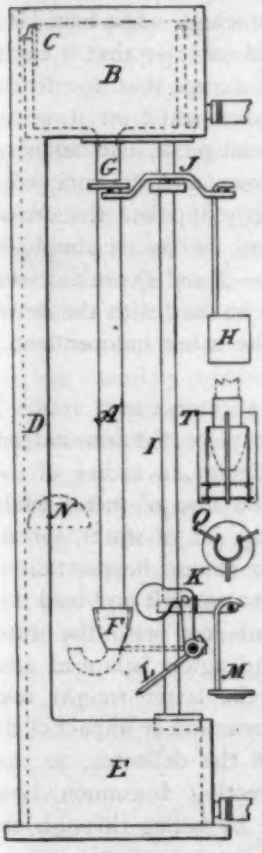


FIG. 13.

The reaction model, with continuous flow, is shown in *Fig. 13*. The vessel *A* has a bore of about half an inch diameter, while the opening at *F* has about half the area of the vessel, so that the velocity of exit is about double that of the flow through the vessel. The supply is maintained constant by a suitably constructed supply chamber, into which the water enters by the hose at the right, and has its velocity checked by a perforated diaphragm, so that the water in the chamber proper is comparatively at rest. *C* is an adjustable weir, by which the height of the water, or "head," can be regulated and maintained constant in spite of slight variations in the supply; the waste water escapes over the weir and runs down the inside of the back *D* into the waste box *E*, from whence it escapes by a hose. The head is regulated to maintain such a velocity in the supply pipe *G*, as will just keep the vessel *A* full, thus delivering to it a jet of suitable velocity and diameter at atmospheric pressure, as explained in a previous part of this article. If the water be delivered at *G* with too great a velocity, the vessel will not receive it all, and if with too little, some air will be drawn in, which will be perceived in the jet at *F*. Rotation of the water entering the

supply pipe, is prevented by suitable guides, not shown. *I* is a brass rod, or tube, which supports the scale beams *J* and *K*, on the former of which the vessel is hung, so as to be exactly under the orifice *G*. The jet piece *F* is detachable so that other jet pieces can be used, as indicated by the dotted piece for delivering a jet vertically upwards; other pieces, for horizontal and inclined jets, can be used, the centres of the jet orifices being all at the same height. *N* is a hood for catching the water from the vertical jet and delivering it down the back *D*. The jet pieces being also all of the same weight the "pee" *H* can be adjusted to balance exactly the empty vessel with jet piece attached. The bent lever scale beam *K* has a counter-balance formed on it, so that it exerts no horizontal pressure on the jet piece, except that due to the weights upon the scale pan *M*. With a downward jet it is not used, but is needed with all others, the thrust piece, also balanced, being raised into the dotted position shown and its knife edge entered into a notch in the jet piece exactly opposite the orifice. With the dotted upward-jet piece shown, its use is simply to maintain the vessel in a vertical position. *T* and *Q* are an elevation and plan of a deflector attachment, to be used with the downward jet for obtaining the reaction of the same independent of other forces.

This deflector attachment consists of a three-armed frame *T*, which slips onto the vessel just above the jet piece, the arms extending past the same and sustaining the deflector in either of two positions beneath it. The deflector is a thin disc of metal which rests in notches in the arms and receives the jet of water, spreading it into a thin sheet and allowing it to escape horizontally in all directions; a cylindrical shield is used to catch it and lead it to the waste box. If the upper scales are balanced with the water running and the deflector not in place, and again balanced after the latter has been inserted, the excess of the latter weight over the former will be equal to the downward reaction or impact of the jet striking the deflector plus the weight of the deflector, so that the reaction of the jet is thus obtained directly. Inasmuch, however, as the velocity of the jet is increased by falling through the distance from *F* to the deflector, there are two sets of notches, so that the deflector can be placed either one or two inches below *F*, and from the difference in weight caused by this change an allow-

ance can be made equivalent to placing the deflector exactly at *F*. With this allowance made the difference in weight equals the reaction of the jet issuing from *F*. The weight of the vessel when the water is running and the deflector frame removed is equal to the weight of the vessel full of water plus the reaction of the entering minus that of the issuing jet, plus the friction along the tube, but the weight of the vessel and water can be found by corking the orifice *F* and weighing it full of water, and the lower jet reaction has been determined as above, so that we get the upper jet reaction and friction from this weighing. It is intended to have a lower jet piece fitting without friction in the pipe, but supported from without, so that the friction of the stream against the pipe can be directly weighed; it has also been proposed to accomplish the same result by hanging a thin band of the same material as the tube from a balance above the supply box, so that this band shall occupy a diametral position along the whole height of the vessel, and thus receive the friction the same as the walls of the tube do. The velocity of the water in the jets must be found by catching it for a definite number of seconds and weighing it, which also furnishes a test of the uniformity of the flow. In the figure, no water is supposed to be in the apparatus, although its level in the supply chamber is indicated by a dotted line.

This apparatus works with great accuracy and a delicate balance can be obtained and maintained. The condition of atmospheric pressure at the point *G* is secured with great nicety by the device of the open space between the supply tube and vessel; to further establish this point an improvement is contemplated by which to test this pressure at any time with a water gauge. The experiments already made have been with the vertical jet only, and they agree well with calculated results.

The MARTIN FIRE-PROOFING PROCESS.

By Prof. Arthur Beardsley.

[*Abstract of Paper read at the Stated Meeting of the* Institute, *September 21, 1887.*]

Many attempts have been made to discover a process for rendering tissues, wood, etc., uninflammable. The fearful losses of life and the great destruction of property by fire make the question one of the greatest importance. The object sought has been the discovery of a means of so protecting combustible materials that they will ignite with difficulty, burn without flame, and cease burning when the source of heat is removed. The objection to former processes has been that the fire-proof quality has not been permanent, causing the necessity of frequent and costly renewal.

The Martin process is cheap, easily applied, is not poisonous or corrosive, does not alter texture or color, and secures to fabrics a *durable* uninflammability. It has been subjected to the most severe tests by the eminent French chemists, Dumas, Paliard and Troost, acting as a Committee of the Society for the Advancement of National Industry, not only in the laboratory, but also in the theatres, the tests extending over several months and to a wide range of combustible materials, with the result that the process is now compulsory in all the theatres of France. Similar tests have been made in Turin, by Profs. Sobrero and Carlevaris, with the most satisfactory results.

In this country, the process has been most thoroughly investigated by Profs. J. Ogden Doremus and Henry A. Mott, who certify that it renders all combustible matter absolutely uninflammable; that it protects wood from decay and from the ravages of insects; that it is a most reliable and effectual fire extinguisher; that its effectiveness is *permanent*; that it is easily and generally applied, and is inexpensive; that it is neither poisonous nor corrosive, and affects neither textures nor colors.

The materials to be treated are dipped into a solution of the "glycero" and left there about fifteen minutes, after which they are allowed to dry, or are ironed dry if desired. As a paint, the "glycero" salts are mixed with the usual pigments and oil, and

applied with a brush in the usual way. Some of the specimens here shown have been treated for several months, one piece of wood having been "dipped" in 1885. Some of these materials are naturally of the most inflammable character, as light dress goods, newspapers, cotton wadding, excelsior, etc., but the "treated" specimens, as you see, defy our efforts to make them burn, simply charring under the intense heat of the Bunsen burner. Its cost is less than one-half cent per yard for the lighter fabrics. The "glycero" composition does not differ materially from other fire-proof compositions, except in the addition of a quantity of glycerine, to which its permanence is due. The composition is made up somewhat differently for different materials, one form of which, as contained in Dr. Mott's report, being as follows:

	Per Cent.
Glycerine, 28° B.,	9·71
Carbonate of ammonia,	4·85
Chloride of ammonium,	38·84
Cream of tartar,	3·84
Oxalate of potash,	3·84
Boracic acid,	38·84
	100·00

Prof. H. A. Mott, of New York, when called upon, alluded to the character of the tests conducted by the Committee to determine the duration of the process, which test consisted in exposing tissues, woods, fabrics of all kinds, which had been treated by the Martin process, to a temperature of 115° F., in an oven for over seven months, during which time currents of dry and moist air were alternately passed through the chamber, the articles thus exposed being as perfect after the test as before.

He then gave the composition of the Martin mixture, and stated that the success of the preparation was due to the presence of glycerine, which tended to hold the salts in solution (so to speak), thus protecting them from being evaporated or vaporized at ordinary temperatures, as it is well known that glycerine does not evaporate. The pressure of glycerine in the salts used for fire-proof paint, seems to prevent crystallization or disintegration of the salts, so that on the application of heat the paint film is more elastic, not cracking like ordinary paint films, thus exposing the untreated wood to the action of the flame, but causing the film to swell and

hold together as the gas generated by the decomposition of the salts form by the application of the flame. Dr. Mott stated that the value of the process consisted in being able to locate the flame or fire, so that it would be unable to spread the flame, simply charring the wood or fabrics at the point of application.

THE GRAMOPHONE.

BY. PROF. EDWIN J. HOUSTON.

The early promises of the actual practical applications of Mr. Edison's phonograph have never yet been fully realized, and this, too, despite the fact that much ingenious work has been expended on its improvement.

The causes of such failure are two-fold:

(1.) The phonograph, as originally constructed, failed to correctly reproduce articulate speech.

It gave readily, with fair accuracy, the pitch of the uttered sounds, and, to a certain extent, reproduced their intensity or loudness; but it failed, almost completely, to give anything but approximations of the loudness or intensity of the overtones on which the quality of the speaker's voice depends. That is, although the spoken words were readily recognized, the speaker's voice could not readily be distinguished, especially when the words spoken into the phonograph were uttered in a loud tone.

(2.) The phonograph-record, as originally obtained, was of a perishable nature, and failed to reproduce the spoken words more than a comparatively few times.

The record was received on a sheet of tin foil, so that when the stylus or point attached to the diaphragm, when used to reproduce the speech, was caused to traverse the record a few times it gradually wore off the ridges, or changed the configuration of the hollows, thus either entirely obliterating the records, or rendering them unintelligible. When used to receive the speech, this diaphragm may be called the transmitting diaphragm; when used to reproduce speech, it may be called the receiving diaphragm.

The difficulties already alluded to arose to a great extent from the fact that in the original form of phonograph the movements of

the diaphragm, under the influence of the sound waves, caused the point attached to said diaphragm to indent the sheet of tin foil, on which the point rested, to depths, the extent of which varied with the amplitude of the vibrations of the diaphragm. The distance between indentations of the same order represented the wave lengths, or, in other words, the record was traced or engraved on the tin foil, as alternate hollows and ridges of varying depths, as must of course have been the case, since the cutting or indenting stylus or point was moved at right angles to the surface of the tin foil.

The extent to which the indentations of the phonogram-record accurately copied the movements of the transmitting diaphragm, necessarily measured the accuracy with which such record could reproduce exactly similar movements in the receiving diaphragm and thus reproduce exact copies of the original sounds. To what extent is this similarity maintained?

Evidently no difficulty exists to correctly impress on the record the frequency of the to and fro movements of the transmitting diaphragm so far as the fundamental tones of the spoken words are concerned, nor, indeed, to a great extent, the relative frequency of the overtones. But, a very serious difficulty arises when it is endeavored to preserve in the record the amplitude of the motion of the transmitting diaphragm, especially the relative amplitudes of the additional or over-tones. The cause of this difficulty is to be found in the fact that the degree of resistance to indentation, offered by the tin foil, or indeed by any ordinary material, does not increase in the same ratio as the depth of indentation, but in a much more rapid ratio. It therefore follows that the relative depths of the phonogram-record indentations are not a correct reproduction of the movements of the transmitting diaphragm, consequently the phonogram-record is unable to correctly reproduce the quality of a speaker's voice, on which a recognition of the same depends.

Under these circumstances, it is evident that there will be a closer reproduction of the quality of any tone, when the same is uttered into the receiving diaphragm in a low tone, since then the differences in the intensities of the over-tones are less pronounced. This fact was noticed, in the early use of the phonograph, but the construction of the apparatus was such as to necessitate the use of

very loud tones, when it was desired to cause the reproduced tones to be heard by many people at once.

It should be borne in mind, therefore, that perhaps the principal cause of the failure of the early form of the phonograph to come into extensive commercial use, did not arise from imperfect or incomplete mechanical construction, or, indeed, from the character of the material employed for the phonogram-record, but from a faulty underlying principle, viz., *from the fact that the recording stylus was moved at right angles to the surface that received its cuttings or indentations.*

The difficulties just pointed out, it would seem, must exist in any instrument, however improved in its mechanical structure, if it makes the record on the phonogram-record at right angles to the surface thereof. Of course, if a substance was discovered for such a surface, that offered a resistance to indentation exactly proportional to the depth of such indentation, the difficulty would, to a great extent, be removed.

It would not, however, be entirely removed. It is essential to the correct reproduction of the movements of the transmitting diaphragm, that the stylus should move over the record-surface without perceptible friction, or at least without any change in the amount of the friction. Unless this is possible the record will, as before, not only be weakened, but modified. It is therefore difficult to see how any form of phonographic or, perhaps more correctly, phonautographic apparatus, in which the stylus moves at right angles to the surface of the recording sheet, can correctly reproduce articulate speech.

The objection to the indenting stylus thus moving at right angles to the surface of the recording sheet is not, however, limited to the failure of the phonogram-record to be correctly impressed with the movements of the transmitting diaphragm. A record so made, as a rule, is incapable of correctly impressing all its recorded peculiarities on the receiving diaphragm; and thus, again, the characteristic movements of the transmitting diaphragm are still further departed from, or, the sounds received, differ still further from the sounds transmitted.

The cause is evident. The receiving diaphragm, as is well known, is caused to move to and fro and thus produce the sounds, by means of a suitably attached stylus, the point of which is caused

mechanically to move over the phonogram-record. As it passes over the indentations, the diaphragm moves in or out, according to whether it is moving up an elevation, or down a depression.

Such motion, however, is positive in but one direction; viz., while the stylus is climbing an elevation or ridge, motion in the opposite direction being produced by the elasticity of a spring or of the diaphragm itself. If, in order to copy all the peculiarities of the record, the tension of the spring, or the pressure of the stylus on the record surface be increased, rapid wear ensues. If, on the contrary, to avoid this, the stylus be rested too lightly on the record, it will often, on the outward movement of the diaphragm, entirely leave the surface, and thus, either greatly mar the clearness of the reproduced sounds, or render them quite unintelligible.

We understand that Mr. Edison has been at work, for some time past, in improving the phonograph as originally created by him, and that he claims to have greatly improved the instrument, and that he will soon place the same on the market.

Meanwhile, however, Mr. Emil Berliner, of Washington, D. C., known to the scientific world from his labors in connection with the telephone, has invented an improved form of phonograph, in which the difficulties heretofore existing in such instruments have been very nearly, if not entirely, removed. Indeed, if what is claimed for the new instrument be true, which from a strictly scientific standpoint certainly appears to be extremely probable, the art of the stenographic reporter bids fair, at least to a considerable extent, to become one of the lost arts.

Mr. Berliner calls his instrument a gramophone, and, under this name, has patented it in the United States, under Letters Patent No. 372,786, dated November 8, 1887.

The following description of some of the forms of apparatus, as well as most of the figures, are taken from the United States Letters Patent before alluded to.

Before entering into a detailed description of Mr. Berliner's apparatus, it may be mentioned that the respects wherein the same differs from the earlier forms of phonograph are mainly two-fold; viz.:

(1.) In the fact that the record is traced on the phonogram sheet in a direction parallel to the surface of such sheet, instead of at right angles thereto as heretofore.

(2.) That in place of a material like tin foil, which is objectionable on account of the resistance it offers to the free movements of the tracing point attached to the diaphragm, there is employed a surface that offers but little resistance to such movements.

These improvements are of a radical character, and will, it is believed, do much to render possible the commercial use of the instrument.

Mr. Berliner's description of the objects of his invention is so tersely put, that we will quote certain parts thereof.

"By the ordinary method of recording spoken words or other sounds for reproduction, it is attempted to cause a stylus attached to a vibrating diaphragm to indent a travelling sheet of tin foil or other like substance to a depth varying in accordance with the amplitudes of the sound-waves to be recorded. This attempt is necessarily more or less ineffective, for the reason that the force of a diaphragm vibrating under the impact of sound-waves is very weak, and, that in the act of overcoming the resistance of the tin foil or other material, the vibrations of the diaphragm are not only weakened but are also modified. Thus, while the record contains as many undulations as the sounds which produce it, and in the same order of succession, the character of the recorded undulations is more or less different from those of the sounds uttered against the diaphragm.

"There is then a true record of the pitch, but a distorted record of the quality of the sounds obtained. The simple statement that the material upon which the record is made resists the movement of the diaphragm is not sufficient to explain the distortion of the character of the undulation, for if that resistance were uniform, or even proportional to the displacement of the stylus, the record would be simply weakened, but not distorted; but it is a fact that the resistance of any material to indentation increases faster than the depth of indentation, so that a vibration of greater amplitude of the stylus meets with a disproportionately greater resistance than a vibration of smaller amplitude."

The difficulties here pointed out are removed by the inventor by the happy idea of moving the recording stylus parallel with the recording surface, as is done in the well-known phonautograph of Leon Scott. This change in the direction of motion permits a ready change in the character of the recording surface.

The structure of the apparatus will be better understood from inspection of *Fig. 1*. In this form of instrument the recording sur-

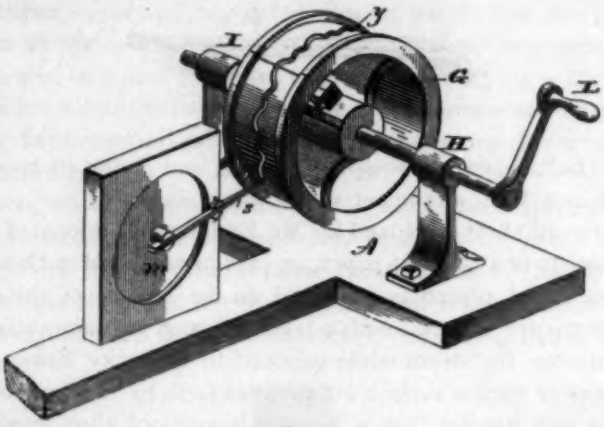


FIG. 1.

face is the surface of the cylinder or drum *G*, mounted on a shaft or axis supported by the standards *H*, *I*, so as to be readily rotated by the winch *L*. The drum *G*, may, as shown in the figure, be provided with flanges *e e'*, *e e'*, *Fig. 2*. *e'* projecting beyond the general

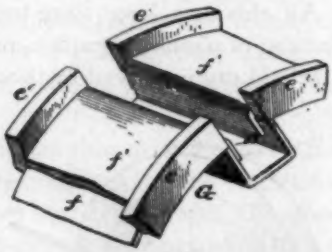


FIG. 2.

surface *f*, of the cylinder. From the edges of a gap *B*, left on the cylinder surface, the side walls of a box *K*, extend as shown.

A layer *f'*, *f'*, of thin felt, or other yielding elastic material, is wrapped on the cylinder surface, and bent over the edges of the gap and serves as the support of the record surface, both while recording and reproducing.

The recording surface is secured at both ends to bars *c*, and *d*, as seen in *Fig. 3*, and is then placed on the supporting surface, the

bars *c*, and *d*, being placed in the gap *B*, before alluded to. The record sheet is tightly stretched on the surface of the drum, by

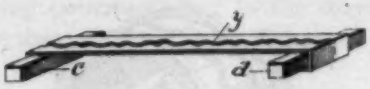


FIG. 3.

means of bolts passing through the bars *c*, and *d*, and its two ends brought into true alignment in the same plane.

The record sheet employed by Mr. Berliner in this form of apparatus consists of a sheet of paper, or parchment, or of a thin strip of flexible metal, placed as described on the surface of the drum, and subsequently covered with a layer of soot or lamp-black by slowly turning the drum while exposed to a smoky flame. The advantages of such a surface are thus set forth by the inventor:

"It is well known that a layer of lamp-black thus deposited, while it adheres well to the surface of a solid body, is nevertheless easily removed from the same. It requires only an exceedingly small force to draw a plainly-visible line upon such surface, owing to the fact that the spicules of carbon of which lamp-black is composed are only loosely superimposed upon each other, and are exceedingly light. All this has long since been recognized and utilized in the production of phonautographic records, and I take advantage of these facts in my improved method of recording and reproducing sounds."

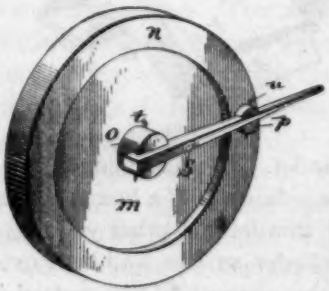


FIG. 4.

The diaphragm *m*, shown more clearly in *Fig. 4*, is rigidly mounted in a frame, *n*, so that its plane is at right angles to the axis of the drum *G*.

A post *O*, attached to the centre of the diaphragm, is furnished with a slot in which is received a stylus *S*, pivoted at *t*. This stylus, which projects over and beyond the frame, has its free end just in contact with the record-surface, and is also pivoted by a pin *u*, in a slot provided in a post *p*, on the frame *n*. The stylus *p*, therefore acts as a lever with its fulcrum at *u*, and the movements it receives from the diaphragm *m*, are limited to deviations practically parallel to the record-surface.

If then, while sounds are directed against the diaphragm, the drum is rotated with uniform speed by means of the crank *L*, the movements of the diaphragm cause the free end of the stylus to vibrate to the right and left of its position of rest, and thus traces on the lamp-blacked surface a sinuous or undulating line *y*, *Fig. 5*.

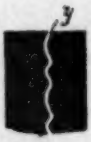


FIG. 5.

A record, therefore, is thus obtained of the sounds uttered against or in the neighborhood of the diaphragm.

It is evident from the nature of the recording surface, and the direction of movement of the recording stylus, that

(1.) That a line of uniform depth is traced in an easily yielding surface;

(2.) The slight friction thus experienced by the recording stylus is independent of the amplitude of the vibrations;

(3.) The vibrations of the diaphragm, therefore, are not modified or changed as in the case of the instruments heretofore in use.

The record having thus been obtained, is then flowed with any quick drying varnish which preserves the lamp-blacked surface. There now remains the process whereby it is copied in solid resisting material. The author mentions three processes; viz.:

(1.) A copy in metal by the purely mechanical process of engraving.

(2.) A copy by chemical deposition.

(3.) A copy by photo-engraving. The latter process is preferred by the inventor.

To the above might be added the process of electro-metallurgic deposition.

The process of photo-engraving is, however, the simplest, and permits not only the most accurate copy to any indefinite extent in copper or nickel, without destroying or injuring the record. A

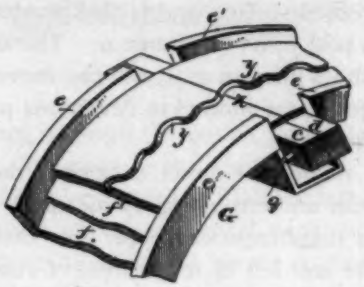


FIG. 6.

record thus reproduced is shown, in *Fig. 6*, attached to the surface of the drum *G*. A section of the same is shown in perspective in *Fig. 7*.

FIG. 7.

The copied or reproduced record is now placed on the drum *G*, as shown in *Fig. 6*, care being taken to obtain an exact meeting of the two ends of the sinuous or undulatory groove. The drum is now rotated, with the same speed as that it had on receiving the record. The end of the stylus is thus forced to follow the sinuous grooves *y*, and the diaphragm *m*, *is vibrated positively in both directions*, and in strict accordance with the undulatory groove. It must therefore reproduce the sounds uttered into the diaphragm correctly as to pitch and quality.

As regards the intensity of the reproduced sounds, it is evident, as the inventor has stated, that since the phonautographic record may readily be enlarged, the intensity or loudness of the reproduced sounds can be increased to almost any desired extent.

That Mr. Berliner's gramophone, or an apparatus constructed in substantial accordance with the novel features thereof, will come

into extended commercial use seems to be rendered probable by the following considerations; viz.:

(1.) It effects such an accurate reproduction of spoken words as to render it possible to preserve the characteristic speech of distinguished people or of friends or relatives.

(2.) The record it produces is imperishable, and will reproduce the original sounds as often as may be desired.

(3.) The record may be indefinitely reproduced, being comparable in this respect with the printed record of a book.

Since the resistance to the movements of the inducting stylus is reduced to nearly a minimum by the use of Mr. Berliner's apparatus, it is evident that the speech may be recorded even when the speaker is talking in an ordinary tone.

Mr. Berliner's claims in the U. S. Patent before referred to are quite broad, as will be seen:

(1.) The method or process of recording and reproducing spoken words and other sounds, which consists in first drawing an undulatory line of even depth in a travelling layer of non-resisting material by and in accordance with sound vibrations, then producing the record thus obtained in solid resisting material, and finally imparting vibrations to a sonorous body by and in accordance with the resisting record, substantially as described.

(2.) The method or process of reproducing sounds recorded phonautographically, which consists in copying the phonautographic record in solid resisting material, and then imparting vibrations to a sonorous body by and in accordance with the copy of the original record, substantially as described.

(3.) The method or process of reproducing sounds recorded phonautographically, which consists in copying the phonautographic record in solid resisting material by the process of photo-engraving, and then imparting positive to-and-fro movements to a sonorous body by and in accordance with the copy of the original record, substantially as described.

A more recent form of gramophone will be seen in *Fig. 8*, the cut for which, and for *Fig. 9*, were kindly furnished by the *Electrical World* of New York.

In this form of apparatus the mechanical details only are altered. The receiving surface is a disc of smooth glass rotated at a uniform rate by the descent of a box loaded with shot. The uniformity of

speed is secured by means of the fan shown at the left of the figure. The recording surface is the lower surface of the glass disc. The stylus and diaphragm are placed as shown, and are connected to a tube furnished with a peculiarly constructed mouth-piece to ensure ease of talking.

FIG. 8.

The glass disc, before being coated with the lamp-black, is covered with a uniform layer of printers' ink by passing an ordinary printers' roll over its surface. Thus prepared it appears to take a more adherent deposit of lamp-black.

In this form of apparatus suitable arrangements are made to give the disc a progressive movement so that the stylus traces the

sinuous, or undulating line in a spiral, such for example as that shown in *Fig. 9*, where a section only is represented.

Whether or not the gramophone will realize in actual practice the numerous practical applications it seems to offer, remains of course to be seen. It has in its favor the advantages already pointed out. It has as a drawback, which may prove to

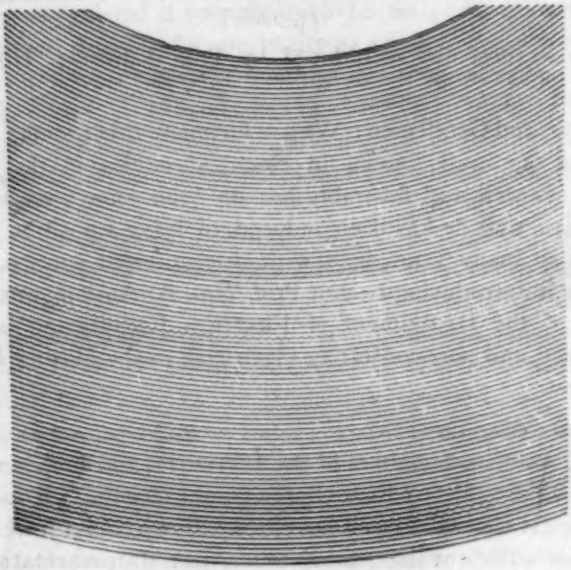


FIG. 9.

be more or less serious, the necessity that exists for the reproduction of the record in hard metal, which involves processes that require long practice and manipulative skill. These, however, are mechanical difficulties, and will, we believe, readily be overcome.

CENTRAL HIGH SCHOOL.
Philadelphia, November 24, 1887.

ELECTRICAL MEASUREMENTS, ESPECIALLY AS APPLIED TO COMMERCIAL WORK.

By Prof. WM. A. ANTHONY.

[*Abstract of a Lecture delivered at the* FRANKLIN INSTITUTE, *November 25, 1887.*]

The lecturer was introduced by Prof. Edwin J. Houston, as follows:

Ladies and Gentlemen: We are fortunate this evening in having with us one well known in electrical circles in this country. Indeed, so well and favorably has he been known as a practical electrician, that he has been induced to leave a position which he has for so many years held with distinguished success. I take pleasure in introducing to you Prof. Wm. A. Anthony, formerly in charge of the Department of Electrical Engineering in Cornell University, and now consulting electrician of the Mather Electrical Company.

PROFESSOR ANTHONY:

Mr. President, Members of the INSTITUTE, and Ladies and Gentlemen—The subject I have chosen for this evening's lecture is one of the driest that could well have been chosen, but I have believed it to be of sufficient importance to warrant its presentation to an audience such as I suppose would be attracted to the FRANKLIN INSTITUTE meetings. Thousands of men and millions of capital are to-day interested in the applications of electrical science. We have come to a point where hap-hazard work is no longer admissible, where electrical currents must be gauged and measured, where the electrical properties of materials must be accurately determined, where, in short, machines and apparatus must be built to a gauge, and their products measured electrically as well as mechanically. As in mechanical construction we have gone beyond the use of the foot-rule and carpenter's square, and are fixing our dimensions by standard gauges to the ten-thousandth of an inch, so in the electrical construction we have gone beyond measurements by rude and imperfect instruments, and have got to a point where, if our machines and apparatus are to find their place in the markets of the world, we must gauge our work by accurate electrical standards.

What are the electrical quantities we have to measure? Before attempting to answer this question, let us consider for a moment the origin of the terms we shall have to use. Our electrical nomenclature has been derived from the fluid theory of electricity. We talk about an electrical current as though something were flowing; we talk about quantity of electricity as though we considered it something to be weighed or measured; we talk about capacity for electricity as though a body could be filled with and hold a certain quantity of it, as a vessel may be filled with water. Whence comes the idea of an electric flow?

If we go back to the early electrical experiments where insulated bodies were "charged" and then discharged—the electricity drawn off, as it were—by a wire connecting the insulated body to the earth, we see that the idea of something accumulated in the body and then conveyed away by the wire was a very natural one, and when we found that the wire was heated, the passage of *something* through it seemed to be proved. Then came the voltaic battery and the evidence of greater and greater effects as the cells in series were increased, a close analogy to increasing pressure causing a more rapid flow of fluid. It was seen that many cells in series gave power of overcoming obstacles, that insulation had to be more perfect to prevent escape. Hence the terms high tension and low tension, as these were applied to gases.

There is some misapprehension among those who have had only a practical acquaintance with electrical phenomena and do not know the fundamental principles. I hear a great deal of talk about high tension currents and low tension currents, as though the currents themselves were different. It should be understood that a current of one ampère is always a current of one ampère, always conveys one coulomb per second whether the tension be high or low, just as a stream that conveys one gallon of water per second, is the same stream whether under high or low pressure. The term tension is a misnomer as applied both to electricity and to gases. Pressure is the proper term for gases and may be used by analogy for electricity. Potential is the scientific term for the electrical condition for which the word tension has been used. We can best understand it by drawing the analogy between it and fluid pressure. We find in the evening that the gas is burning dimly. We say at once, too little pressure in the mains.

If more pressure is put on, more gas is forced through the burners and our lights burn more brightly. If our incandescent lights burn dimly, it is a lack of potential. Let the potential in the wires be increased, more electricity is forced through the carbon filament with an improvement in the light. It is not the greater pressure that gives you the brighter gas light, but the larger quantity of gas that the greater pressure supplies. So it is not the increased potential that causes the increased brightness of the carbon filament, but the greater flow resulting from the higher potential.

The electrical quantities we wish to measure are then *quantity*, which is measured in units called *coulombs*, and may be considered as analogous to pounds of a gas or liquid:—*potential*, measured in *volts*, analogous to pounds per square inch of fluid pressure:—*capacity*, measured in *farads*, analogous to cubic feet of a vessel for holding fluids:—and *strength of current*, measured in *ampères*, for which there is no close analogue in fluid measurements. Yet in electrical measurements, strength of current is, perhaps, most important of all, and furnishes the fundamental unit of the system. Another quantity of great importance in electrical measurements is the *resistance* of bodies to the flow of electricity. It is measured in *ohms* and may be compared, qualitatively, to the frictional resistance which fluids experience in flowing through pipes.

Let us consider now these several quantities and their relations to each other, from the standpoint of the analogy of a flowing fluid. Here is a pipe carrying gas. We wish to know how much gas is flowing through it per hour or day or month. This the gas meter professes to tell us, but there is sometimes a question whether its statements are truthful. We could run the gas into a suitable vessel and measure it, but that would be inconvenient in the practical use of the gas because we consume it as it flows. But whatever method we use, our object is to determine the total quantity of gas delivered in a given time, and not the rate of flow at any instant. By *rate of flow* I do not mean the velocity of the gas, but the rate as indicated by the quantity of gas flowing in unit time when the flow is uniform. In this sense, when the same quantity of gas per minute is flowing, the rate of flow is the same whatever the size of the pipe. But there is no important effect of the gas dependent upon the rate of flow; the pipe that conveys it acquires no new properties or

powers. In fact, no effect is produced by it that would indicate to us whether the gas were flowing or not. To be sure, heat is generated by the friction of the gas, but in practice this is too small to be perceived and is of no consequence. Moreover, the heat generated is a function of the velocity of the gas and not simply of the rate of flow as I have used that term. We have, therefore, no need to know the rate of flow of a gas, we make no attempt to measure it directly, we have no unit in which to express it, and no distinctive name for it as a quantity.

Now let us compare an electric flow. Here is a wire conveying an electric current. We know there is something going on it because we see the effects on beyond, just as we know that gas is flowing in this pipe because we see it burning in yonder burner. As with the gas, we can determine the quantity of electricity flowing in a given time by measuring its effects. Electricity flowing through acidulated water generates hydrogen and oxygen gases. The quantity of these gases generated in a given time may be taken as a measure of the total amount of electricity flowing. Electricity flowing through a solution of a metallic salt, as copper sulphate or silver nitrate, deposits the metal. The weight of deposited metal will measure the total flow. But these methods, like the methods of measuring gas, tell us only the average rate of flow and not the rate at any given time. But, a conductor conveying electricity, unlike a conductor conveying fluid, exerts forces due to the current in it. This wire will deflect a magnetic needle, will attract iron filings. (Shown by experiment.) In short, it develops all around it a magnetic field.

This effect of an electric flow is of such great importance and finds such a multitude of applications, that the rate of flow upon which it depends is a more important element than the total quantity flowing, and the unit in which we measure it, the ampère, is based upon this magnetic effect. This unit has taken its place with our foot, and pound, and gallon, and is making its way very rapidly into the popular vocabulary. Notwithstanding the fact that it is coming into such general use, there seems to be a great deal of confusion as to what an ampère is. It seems to me important that the true definition of this unit current should not be lost sight of, and I wish to protest against the admission of the

arbitrary definitions that are finding their way into electrical literature.

The true ampère is based upon the absolute unit current as defined by the British Association committee. The absolute unit current is that current, a centimeter length of which will produce a unit magnetic field at a centimeter distance, or it is that current which when flowing in a conductor bent into a circle of one centimeter radius, will develop at its centre a magnetic field of intensity 2π. This is the foundation of the electro-magnetic system of electrical measurements. Upon this unit are based all the other units of the system. The *ampère is one-tenth of this unit.* This was the value of the weber, the former name of the unit of current, and the Paris congress, in changing the name to the ampère, did not change its value, but expressly voted that this should continue to be its signification.

Now to measure an electric flow in ampères. We may bend the conductor into a circle and compare the field produced at the centre of the circle with some known magnetic field, such as the magnetic field due to the earth. This is accomplished by means of the tangent galvanometer. The conductor, of one or many circular convolutions, is placed with its plane in the magnetic meridian; in this position the force it produces is at right angles to the earth's magnetic force and a little needle placed at the centre of the circle will take a position depending on the ratio of the two magnetic fields. If the needle stand at 45° with the magnetic meridian, the two fields are equal, and, in general, the ratio of the field produced by the current to that of the earth, is the tangent of the angle that the little needle makes with the meridian.

In the great tangent galvanometer of the Cornell University, this method is employed to measure currents up to 300 amperes. The great difficulty in this method is that the earth's magnetic field is not constant but varies from day to day and from hour to hour. In all work where accuracy is aimed at, the horizontal intensity of the earth's magnetic field must be determined at the time of making an observation for current. In the Cornell instrument a coil suspended by a wire serves to determine the horizontal intensity by balancing the force developed by a current in the coil in the earth's field against the force of torsion of the suspending wire. But another and more serious difficulty is met with when any

attempt is made to use this method for ordinary practical work. The earth's magnetic field is greatly affected by the presence of magnetic substances. A small mass of iron is sufficient to change very greatly the value of the earth's field in its vicinity. A large magnet or a dynamo may at many feet distance change the earth's field by a hundred per cent. The tangent galvanometer can only be used, therefore, where there are no disturbing causes. It cannot be used in a dynamo station or in a workshop. But in a suitable place, it is invaluable as a standard with which to compare other instruments. The Cornell tangent galvanometer is mounted in a special building, constructed entirely without iron and placed at a distance from all other buildings. The earth's field there is subject only to such changes as are due to natural causes, and with the appliances for determining these changes the highest class of work can be done.

We need, however, instruments for measuring currents in the workshop and about dynamo machines, and a great variety of instruments called ammeters have been constructed for these purposes. In general, such instruments consist of a coil of wire developing a magnetic field which is compared with an artificial field produced for the purpose, or the magnetic force developed by the coil in the presence of some other magnetic field is balanced by some known force. To be more explicit, one form of ammeter consists of a coil which tends to deflect a needle against the artificial field of a permanent magnet. The accuracy of these instruments depends upon the constancy of this opposing field. But no permanent magnet does remain constant, and these instruments, therefore, need to be frequently calibrated. Another form of ammeter is one in which the coil acts upon a mass of soft iron, developing a force which is opposed by a spiral spring. Here the accuracy of the instrument depends upon the constancy of the spring and upon the constancy of the effect of the little mass of iron.

And here let me say that a magnetic field is not of itself a force. To have *force* there must be two magnetic bodies, and the force exerted depends as much upon the one as upon the other. A coil of wire conveying a current develops a magnetic field, but before a force can be produced something else that can also develop a magnetic field, as a mass of iron, a magnet, or

another coil of wire carrying a current, must be brought within the range of its action. If this second body can only produce a weak field, then only a feeble force will be produced. Moreover, the force will vary with every change in this second body, even if the current in the primary coil remain constant.

Speaking of this fact, of the necessity of two magnetic bodies to develop a magnetic force, reminds me of a question often asked in regard to extracting particles of steel that have become imbedded in the eye. Would not a sufficiently powerful magnet draw it out? I always tell the questioner that the most powerful magnet in the world could exert but a small force upon a little particle of steel. If you can loosen the piece of steel, a magnet is a very good means of taking it out of the eye, but then a small magnet does as well as a large one. I was once told by a gentleman that he had known of a sewing needle that was deep down in the flesh of the leg being drawn out by the application of a powerful magnet. I remembered how little force the most powerful magnet can exert where a sewing needle is the body attracted, and thought to myself that the statement needed confirmation. Some of you will remember that when it was proposed to build the 1,000 feet iron tower in Paris, it was predicted that all the loose iron articles, knives, joiners' tools, chains, tin pans, to say nothing of wagon tires and horse shoes, would come rushing pell-mell to the base, in consequence of the tower becoming a great magnet by the earth's induction. Yet, notwithstanding the prediction, I do not think I should take the precaution to leave my keys and pocket knife this side the water if I were going to visit Paris after the erection of the great tower

But to return to our ammeter, the little mass of iron is attracted by the coil, because it becomes itself a magnet. If it become a strong magnet, it is attracted strongly; if it become a weak magnet, it is attracted feebly. Its magnetic strength will not be the same under all circumstances, and the force exerted by the coil upon it is, therefore, not always the same when the same current is flowing. I have recently re-calibrated an Ayrton and Perry instrument of the permanent magnet type, and found its constant had changed sixteen per cent. since last March. Last spring I calibrated two spring ammeters at the same time, and found one to read five per cent. fast, while the other was nearly as much slow

Do not understand from this that I consider these instruments of little value: They are the best we have. What I want to impress upon you is the importance of frequent comparison of the instruments with others known to be standards. Theoretically, the best ammeter is one in which the force exerted between two coils in the same circuit is opposed by gravity. Here the force developed depends only upon the current which it is desired to measure, and the opposing force is the one force at our command that does not have to be watched and tested, but is the same to-day as yesterday, and can be trusted to be the same to-morrow as to-day. Such an instrument would, therefore, give uniform indications. (Thomson instruments exhibited.) There are, however, practical difficulties in the way of constructing such an instrument for the measurement of large currents. One of the coils must be movable, and it is difficult to take a large current to and from it without imposing some constraint upon its motion. We still want for commercial use a really good ammeter for measuring large currents, one that we can trust as we trust our scales for weighing merchandise, to give correct indications for weeks and months and years.

I have dwelt thus upon these instruments, which measure rate of flow, because, as I have already said, some of the most important effects of electric currents depend upon this element. There are cases, however, where we wish to know the total quantity of electricity flowing in a given interval, and care nothing for the rate of flow at any given instant during that interval. For instance, we are furnishing a house with incandescent lights. It is important to know the quantity of electricity furnished per month. The unit in which we measure electricity in such cases is the quantity conveyed in one second by a current of one ampère. This is the coulomb already spoken of. It has not been found easy to construct a reliable coulomb-meter. The Edison Company use a meter in which the current deposits zinc upon a zinc plate. This is a very good method for the laboratory, but it is difficult in practice to fulfil all the requirements for completely reliable meters. At least, so far as I can learn, neither the consumers nor the company seem to be perfectly satisfied. The new coulomb-meter exhibited and described by Prof. Forbes about a month ago, at a meeting of the Electrical

Engineers in New York (and in this Hall) depends for its action upon the development of heat in a wire by the flow of the current. The wire, in the form of a flat spiral, is placed below a little windmill. The flow of electricity in the wire heats it, and so sets up air currents that cause the little windmill to revolve. A train of wheel-work, connected with the windmill, actuates the hands in front of a dial. Thus the instrument registers the flow of electricity as a gas meter registers the flow of gas. Practical experience only can tell whether this instrument will fulfil all the requirements.

But the measurement of currents or of quantities of electricity is but a small part of what is required in electrical measurements. Potential in many cases is quite as important an element as strength of current or quantity. To go back to our analogy of a flowing fluid, we know that pressure is necessary to bring our gas to the burners, but so long as it is sufficient to supply gas in proper quantity and gives us a good light, we do not trouble ourselves about it. It is the business of the gas company to maintain the required pressure, and they must adjust by a pressure gauge. It is the chemical energy of the gas that gives the light, and the energy due to the pressure is too small an item to be considered. But suppose we are supplying steam or compressed air for driving engines, the pressure is now a more important item. The power used is the product of pressure by volume of steam used per second. Pressure is, therefore, one of the items that the consumer pays for. Where electricity is supplied for any purpose, the energy which the consumer pays for is the product of potential by quantity. Varying either factor varies the energy delivered, and measurement of potential is, therefore, as important as measuring quantity or current. The unit in which we measure potential is based upon the relation just stated, that the product of potential by quantity gives the electric energy. The absolute unit potential is the potential under which the absolute unit current performs the absolute unit work in unit time. A true volt is 100,000,000 absolute units.

Before taking up the methods of measuring potential, let us consider the other electrical units and their relations to those already defined. The farad, the unit of capacity, is the capacity of a body which contains one coulomb when charged to a potential of one volt.

At a potential of two volts, the same body would contain two coulombs, but its capacity is still one farad. It is as though we were to define a gallon as the capacity of a vessel which holds one pound of air under a pressure of one atmosphere. Under two atmospheres the same vessel would hold two pounds, under half an atmosphere half a pound.

The ohm is the resistance of a conductor in which the volt maintains the current of one ampère. These are the true definitions of these units and need to be carefully considered when our measurements involve the determination of electric energy. To see how this is important let us consider the actual measurement of a resistance. To measure a resistance upon the basis of the definition just given is a very difficult operation. So difficult that even after twenty-five years of such measurements we do not feel very certain of the value of the ohm. In 1862, the British Association appointed a committee to determine the ohm and construct standards. After some years of labor, standards were produced, consisting of coils of wire supposed to have the resistance defined as the ohm. From these, resistance boxes are constructed and resistances are measured by comparing the unknown with these known resistances. This is a very simple matter and can be quickly and accurately done. The difficulty of measuring a resistance upon the basis of the definition of the ohm, is shown by the fact that later determinations indicate that the British Association standard, now known as the B. A. ohm, is about one and three-eighth per cent. too small. The Paris Congress, recognizing the difficulty of arriving at a positive value on account of the discrepancies between the results of different observers, adopted a standard, the resistance of 106 centimetres of mercury one millimetre in cross section, to be called the *legal ohm*. This, according to the best of our present knowledge, is about one-quarter of one per cent. too small. They further decided that the unit current should retain the value assigned by the British Association, and adopted as the *legal volt* the potential difference that maintains a current of one ampere in the legal ohm. The legal volt is, therefore, about one quarter of one per cent. too small.

Now suppose we have measured a current in ampères and the potential in legal volts; multiplying, we obtain the energy,

but, since the unit in which potential is measured is too small, the result is too large and must be reduced one-quarter of one per cent. to obtain the true energy. I think it unfortunate that the legal standard was not made 106·25 centimetres of mercury, for it seems certain that this amount, to the fourth figure at least, is the correct value of the ohm. If the legal ohm had been so chosen, computations of energy based on measurements in legal units would not have been in error by more than one-tenth of one per cent., and for all ordinary purposes corrections would have been unnecessary. The measurement of a potential in legal volts is not a difficult matter. It consists in measuring the current maintained in a conductor whose resistance is known in legal ohms. A standard instrument for such a purpose would be a delicate galvanometer whose coils consisted of many turns of wire of a known high resistance—of high resistance, because the instrument must take so little current from one point to the other as not appreciably to alter the difference of potential between them. (Experimental illustrations.) A multitude of volt-meters for commercial measurements are on the market, most of them being instruments similar to the ammeters already spoken of, but with coils of very fine wire in which a current, proportional to the difference of potential, is produced. In fact, the ammeters and volt-meters often look so much alike that they could not be distinguished, except for the words "volts" and "ampères" on the dial. These instruments are as likely to change as the corresponding ammeters and require the same precautions as regards calibration.

But there are other ways of measuring potential that do not depend on the measurement of a current. If two plates are connected, one to one point and the other to another, the difference of potential between which is wanted, these two plates, when brought near together, attract each other with a force proportional to the potential difference. This force of attraction is, however, very small and requires an extremely delicate instrument to indicate it, until the potential difference is 400 or 500 volts. (Thomson's voltmeter shown.) Another method of measuring potential is to balance the unknown against a known potential. The difficulty in applying this in practice is to obtain a reliable standard. Voltaic cells afford the best means of obtaining a fairly constant potential difference, but only under very exact conditions are these potentials

sufficiently uniform to be accepted as standards. (Potentials of cells measured.) A gravity cell that had been in use some time gave a deflection of 46. One set up about eight hours before the lecture gave 64, and one set up just at the beginning of the lecture gave 65.

A form of instrument known as the Wirt volt-meter, as furnished by the Electrical Supply Company, of Chicago, uses the Daniels cell, of special construction, as a standard. The cell consists of three square bottles cemented together side by side. In one of the outside bottles is the zinc in zinc sulphate, communicating with the middle bottle by a small hole near the top. The other outside bottle contains the copper in copper sulphate and communicates with the intermediate bottle by a hole near the bottom. In the middle bottle is a valve which when closed prevents communication between its upper and lower parts, and so prevents the mixing of the two liquids. This valve is to be opened only at the time of making an observation. No doubt such a cell made up from pure materials would give the same potential for a considerable time.

I have so far avoided the use of the term electro-motive for I find there is a good deal of confusion as to the exact use of it even among physicists. I find it stated in some works of high authority that electro-motive force and difference of potential are synonymous terms, and again that difference of potential produces electro-motive force. I have seen it stated in a very excellent text-book on electricity by one of our foremost electricians, that the electro-motive force of a voltaic cell is the result of the difference of potential between the poles.

I can best illustrate what I conceive to be the difference between the two terms by referring again to the analogy between the electric flow and the flow of fluids. Gas is flowing through this pipe. Take two points, A and B, and suppose the flow to be from A toward B. A pressure gauge would show a higher pressure at A than at B. Water flows in your water mains. A pressure gauge will show a higher pressure at any point than at any other point further on in the direction of the flow (it is supposed that the points considered are at the same level). The difference of pressure is the cause of the fluid flow. It is the force that moves

the fluid, the *fluid-motive force*. Electricity is flowing along this wire.

I have shown that there is a difference of potential between the different points along the wire, and we accept that difference of potential as the cause of the electric flow between the two points. If we know nothing of the pipe except between the two points considered, we cannot assign any other cause for the flow of the fluid through it except the difference of pressure, but we know the difference of pressure must have a cause, and if we are at all inquisitive we shall not be satisfied with saying the difference of pressure is the fluid-motive force, but we shall trace the pipe back and try to discover the cause of the difference of pressure. Tracing the pipe back we find, by and by, a stand-pipe in which the water level is far above any of the outlets from which water is drawn. This accounts for the pressure of the water in the pipes, but still we are not satisfied. There must be a cause for the high level in the stand-pipe. Investigating further, we find a system of pumps which forces the water into the stand-pipe, taking the water, perhaps, from the same level to which our pipes discharge it. Here we find a water-moving force that is not water pressure, without which the pressure that moves the water in our pipes would soon cease, and the flow stop.

Suppose now that all our outlets are stopped and that no water flows from the stand-pipe. What results? The pumps go on working, the water in the stand-pipe rises higher and higher, and if the pipe is high enough and strong enough, the water will rise till the force of the pumps is balanced, and they will stop. The pressure now exerted by the water column measures the water-moving force of the pumps. We can tell by it just what is the force we have at command for moving water. This force is the water-motive force of our system. It must be sufficient to overcome the resistance of our pipes and carry the water to the highest levels we wish to reach when the flow is most rapid. Open a cock, the water flows and lowers the level in the stand-pipe, the back pressure upon the pumps is diminished, they begin to work, and maintain the water at nearly its former level. Open another cock, the level falls a little more and the pumps work faster. Make more and more openings, and the water in the stand-pipe falls more and more till, by and by, the level in the pipe is but little above that of the supply

from which you pump. Water is being used at such a rate that the force of the pumps is little more than sufficient to drive the water through their own passages. It is not the water-motive force that has failed, but the carrying capacity of the pumps.

Now note the analogy in the case of the voltaic cell. We have found on this wire a difference of potential from point to point. Trace the wire back and we find an apparatus whose office it is to maintain the potential difference. What is its action? By some means, which we do not understand as well as we understand the action of a water pump, this apparatus takes electricity from one of the plates, *N*, in the liquid and forces into the other, *P*. In the second plate, *P*, the electricity is at a higher level, and so flows through the wire to the plate *N* to be forced back to *P* through the liquid. Cut the wire and almost at once the electricity in *P* reaches the highest pressure, level, or potential, that the cell can produce. All action in the cell ceases, and the difference of potential between it and *P* now measures the force the cell can exert to move electricity, the *electro-motive force* of the cell. This electro-motive force is something that depends upon the materials of which the cell is made, and is absolutely independent of its size. The smallest cell, one made of a copper musket cap holding a drop of water, and a bit of zinc of the size of the point of a pin, as I have often shown experimentally, has the same electro-motive force as a cell of the same materials of the largest size; just as the water motive force of a small pump, its power to produce pressure, may be just as great as that of a larger one. Let us follow the analogy. I connect *P* with *N* by a small wire. This is like opening a single stop-cock on our water service. The electric level is lowered, but the cell begins to work and maintains the potential at very near its highest value, another wire allows more electricity to flow, still more lowering the potential, and it is possible to open so free a path for the passage of the current that the cell can no longer maintain a considerable potential difference, and the limit of the capacity of the cell to supply electricity is reached.

Note that the limit here is not due to any falling off of electro-motive force, but to the fact that nearly the whole electro-motive force is required to carry so much electricity across the liquid from plate to plate. Here exactly is the advantage of a large cell over a small one—a large cell, like a large pump, can maintain a high

pressure, even when there is a large draft upon it. I think you will now see the distinction between the terms difference of potential and electro-motive force. Difference of potential is *one* electro-motive force. But the general term, electro-motive force, includes all causes of the movement of electricity. There may be a flow of electricity without a difference of potential, but there can never be a flow without an electro-motive force.

I could give you examples of a great variety of electro-motive forces, but one more will suffice.

I move this rod across the earth's magnetic field. I know that an electro-motive force is developed, causing a flow toward the end at my left hand. That end, I am sure, is for the moment at a higher potential. When I stop, the electricity flows back and equalizes the potential. Connect the two ends by a wire leading to a sensitive galvanometer, and the flow of current is demonstrated. This movement of a wire across any magnetic field develops a difference of potential between the two ends, and if the wire form a closed circuit, a current will flow. I said just now that we could have a flow without difference of potential. Here is a case. A magnet thrust end-on into the centre of a wire hoop produces an electro-motive force, which acts equally all around the hoop, causing a flow, but without difference of potential. Here, too, we may find an analogy in the flow of liquids. Suppose a trough in the form of a ring to contain fluid, and let an endless rope be laid in it and made to move around the trough. (Illustrated on black-board.) The liquid will be dragged along by the rope, but there is no difference of pressure or level anywhere.

Following out this analogy to fluid motions is very useful in leading to clear views of very many other electrical phenomena, for, although nothing is really explained, an unfamiliar fact seems to us more plausible when we find in it a close analogy to a fact with which we have been long familiar, and about which we have no question. Take the case of the operation of electric motors. We know that an electric motor develops an opposing electro-motive force, and every electrician knows that this opposing electro-motive force is the secret of the operation of the motor, that mechanical power cannot be developed without it, but I find that few people except those familiar with the theory, are willing to believe that this counter electro-motive force

is of any use. I have known of some motors being constructed with the avowed object of reducing the counter electro-motive force as much as possible, with the idea that it was a hurtful resistance, preventing the motor from developing its full power. But how is it with a fluid flowing through a pipe? In order to make it do work we must construct a machine to produce a counter pressure. A water motor always checks the flow of water.

Take the simple case of a rotary motor. (Rotary motor on blackboard.) Let it run at full speed and suppose there is no friction. It offers no resistance to the flow of the water. The water flows with the same velocity as though the motor were not there and it does no useful work. Begin now to load the motor, you check its speed and at the same time check the flow of water. As you increase the load you check the flow more and more. The force exerted upon the motor will be greatest when it is brought to rest, and the flow in the pipe stopped; then the water will exert its greatest pressure, but since the motor does not move, it can do no work. Between these two conditions of no power to do work, when moving with the full velocity of the water but without force, and when receiving the full pressure of the water without moving, there must be a condition of maximum power, or maximum rate of working, and we can readily admit that this occurs when the back pressure of the motor is half the *water-moving force*. At this speed half the *water-moving force* is effective in running the motor and half goes to waste in the velocity with which the water leaves the motor. The efficiency of the motor is, therefore, only fifty per cent. It would be far better, if so much power is needed, to use a larger motor and run it at slower speed and at less than its maximum power, and let less of the energy of the water to go to waste.

Now, note the analogy between this and the electric motor. When the electric motor is running it develops a counter electro-motive force which corresponds to the back pressure of the water motor. When this counter electro-motive force equals half the electro-motive force of the generator, the electric motor is giving its maximum power; but it is using only half the energy of the electric current, the other half going to waste in developing heat in the conducting wires leading to the motor, and in the motor itself. Just as with the water motor, it is better to use a larger size

electric motor and let it run at such a rate that it will develop a counter electro-motive force equal to more than half the electro-motive force of the generator, and while developing less than its maximum power perform a work equal to a larger percentage of the energy given to it. The difference between the water motor, which I have taken for an example, and the electric motor, is this, that while the water motor exerts the greatest back pressure when it is stopped, the electric motor exerts the greatest counter electro-motive force when it is running at the highest speed. Otherwise, the analogy between the working of the two is very close, and the efficiency of either one of them is exactly the ratio of the back pressure which it exerts to the possible pressure which can be brought to bear upon it.

In bringing this lecture to a close I wish to acknowledge my own obligation to Mr. Ives, who has kindly loaned and operated his lantern for projecting the views on the screen; to J. W. Queen & Co., for the loan of nearly all the apparatus used and exhibited here this evening, and to Mr. C. H. Richardson and Mr. Metzgar of the firm of Richardson & Metzgar, who have given their services for the whole day, with the resources of their workshop, for the preparation of the apparatus for the experiments. Without their assistance the preparation of the experimental illustrations would have been impossible. Thanking you for your kind attention, I now close.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

TWO CRYSTALLIZABLE BODIES, PTEROCARPIN AND HOMOPTEROCARPIN EXTRACTED FROM SANDERS.—R. Cazeneuve and L. Hugouneng, *Ann. Scien. Indust. de Lyon* (through *Jour. Soc. Dyers and Colourists*, **3**, 9).

The first researches upon the chemical composition of sanders wood are due to L. Meier, who isolated from it a red crystallizable body, which he called santalin. He extracted the santalin by exhausting the wood with ether; the extract was washed with water and dissolved in alcohol, and then precipitated with acetate of lead, the liquid being afterwards freed from lead by means of sulphuretted hydrogen or sulphuric acid, and the santalin separated out.

Weyerman and Haeffely, as the results of analyses, gave the formula C_{15} H_{14} O_5 to the body prepared according to L. Meier's directions.

Weidel treated the wood with a boiling alkaline solution, and then filtered and neutralized the liquid; from the precipitate formed, which was dried, he separated, by means of ether, a colorless crystalline body, which he called santal, and to which he gave the formula C_8 H_8 O_3 + ½ H_2 O.

On treating with alkalies santal forms protocatechuic acid and carbonic acid like piperonal, with which it is isomeric.

On completely exhausting sanders wood, Weidel separated from the last extracts an irregularly crystalline body, colorless, like the santalin of L. Meier. Weidel gave this new body the formula C_{14} H_{12} O_6.

Later than 1878, Franchimont and Sicherer separated from sanders and caliatur wood an amorphous body, melting at 104°, and having the composition C_{17} H_{16} O_6. When this body is treated in a closed vessel with hydrochloric acid, about one molecule of methyl chloride is formed from one molecule of the body.

A black resin remains, from which an amorphous body C_8 H_{10} O_5 can be extracted; from the acid solution left, a body crystallizes out in needles, but has not been further examined.

Three years previous to the publication of the last research, in 1875, one of the authors, by exhausting with ether an intimate mixture of powdered sanders wood and slaked lime, had obtained a well crystallized body having the formula C_{12} H_{10} O_3. This body, differing from the bodies previously mentioned, was shown on further examination to be a mixture.

The powdered sanders wood is intimately mixed with its own weight of freshly-slaked lime. It is moistened with water and dried on a water bath, and then exhausted with ether.

The lime forms an insoluble lake with the coloring matter, and with the resins it forms resinates which are not very soluble. On distilling to dryness, the ether passes over yellow in color, and the residue is redissolved in the smallest possible amount of alcohol of B. P. 93°. On cooling, two bodies—pterocarpin and homopterocarpin—crystallize together, mixed also

with resinous matter; a second crystallization leaves them almost pure; on crystallizing from boiling ether, the mixture of the two bodies separated. The laminated crystals of homopterocarpin are easily distinguished from the long needles of pterocarpin. The two bodies are separated by means of pure carbon bisulphide, which easily dissolves homopterocarpin in the cold, and leaves the pterocarpin almost untouched, as it is only soluble in a large excess of the boiling solvent.

The sanders wood contains almost five grammes of homopterocarpin and one gramme of pterocarpin per kilogramme.

PTEROCARPIN.

This body is white, well crystallized, insoluble in water, insoluble in cold alcohol, more soluble in boiling alcohol, and not very soluble in ether, from the boiling solution of which it separates in laminated crystals. Bisulphide of carbon does not dissolve it in the cold, but dissolves it better boiling. It separates from chloroform in fine prisms.

Pterocarpin turns the plane of polarized light strongly to the left.

On the following percentages an analysis showed it to possess the empirical formula $C_{10}H_8O_2$. It is neutral in its reactions, insoluble in acid, insoluble in concentrated potash, even at the boil; it is acted on by melted potash, and gives an odor resembling cumarine; nitric acid dissolves it with a green color.

HOMOPTEROCARPIN.

It forms a white, well-crystallized substance, soluble in ether, chloroform, bisulphide of carbon and benzene. Alcohol dissolves it very little in the cold, but easily at the boil, and it separates on cooling in splendid needles several centimetres in length.

Like pterocarpin it turns the plane of polarized light to the left.

Homopterocarpin corresponds to the formula $C_{12}H_{12}O_2$, there being a difference of $2\,CH_2$ from pterocarpin.

Concentrated potash (forty per cent.) does not affect homopterocarpin, even on heating to 200° for four hours in a closed vessel.

Melted potash affects it at 240°, white fumes being given off, and an odor of cumarine, when it is dropped on the potash in small portions. The body is thus decomposed, forming carbonic acid, and a phenol giving the color reactions of phloro-glucin, which is extracted with ether after neutralizing the potash with sulphuric acid.

On heating five grammes of homopterocarpin with ten grammes of concentrated hydrochloric acid in a sealed tube to 120°, a black metallic-looking resin is obtained, like that obtained by Barth and Weidel on heating resorcin with concentrated hydrochloric acid in sealed tubes to 190°. These chemists obtained in this way resorcin ether $OH \cdot C_6H_4 - O - C_6H_4 \cdot OH$. The body thus obtained is separated in the same manner as that obtained from homopterocarpin. The acid remaining in the tube is colored yellow. If the acid is evaporated and the residue taken up with ammonia, a fluorescent coloring matter is obtained, having the appearance of fluorescein. Methyl chloride

can be detected in the tube by the green color of its flame and the formation of methyl sulphide.

These reactions seem to show that homopterocarpin is a polyatomic phenol containing methyl groups. From its stability in presence of alkalies, it appears to be an aromatic anhydride of the cumarine series.

Pterocarpin probably belongs to the same group. H. T.

DETERMINATION OF POTASSA IN ASH, MINERALS, MANURES, ETC.—In order to avoid repeated and troublesome evaporations, Kretschmar (*Chemiker Ztg.*, **87**, 418), recommends the following simplification of Stohmann's method whenever potassa alone is to be determined:

Five times the quantity of material required for a potassa determination is dissolved by means of hydrochloric acid, if possible, the iron oxidized by a few drops of nitric acid, and the sulphuric acid precipitated by barium chloride, and the solution then super-saturated hot with ammonia and carbonate of ammonia.

The mixture (solution and precipitate) is then evaporated to dryness in a porcelain dish at least at a temperature of 110° C. After adding a few drops of ammonia, the residue is extracted with hot water. The solution is made to measure 500 c. c., and 50–100 c. c. are taken for the determination of potassa. If little magnesia is present, the solution is evaporated immediately in a platinum dish, and, after expelling ammonia salts, treated with solution of platinic chloride. The presence of a large quantity of magnesia requires a prolonged washing of the platinic double chlorides, because of the difficult solubility of the magnesium platinic chloride. In this case, it is preferable to previously evaporate the measured quantity of the filtrate with an excess of oxalic acid, and after gentle igniting, re-extracting and filtering, the solution is then precipitated with platinic chloride.

This method is applicable in presence of the acids of sulphur, silicic, phosphoric, boric, hydrofluoric acids, iron, aluminium and chromium, the alkaline earths and magnesia and small quantities of manganese. O. L.

COLLOIDAL CUPRIC SULPHIDE. W. Spring and G. de Boeck (*Bul. Soc. Chim.*, **48**, 165).—Among the probable causes of the solubility or insolubility of substances in any liquid, the degree of condensation or polymerization is one of the most important, and the insoluble substances may be regarded as polymerides of others, capable of existing in simpler forms. The number of mineral substances presenting a soluble and an insoluble modification is as yet quite limited, the hydroxides of iron and aluminium, and the sulphides of arsenic and antimony being the best known. A solution of cupric sulphide may be prepared by precipitating any cupric solution by hydrogen sulphide and washing the precipitate with an aqueous solution of hydrogen sulphide. As the foreign matters are removed, the cupric sulphide gradually dissolves, yielding a liquid that is black when examined in mass, but brown when viewed in thin layers, and having a feeble greenish fluorescence. The best results are obtained by the precipitation of an ammoniacal copper salt.

When the solution is boiled, the hydrogen sulphide may be completely expelled without notable precipitation of cupric sulphide, and the analysis of

the liquid then shows that the proportions of copper and sulphur are exactly those required for the formula CuS. Such solutions keep well if the proportion of cupric sulphide is not greater than five grammes to the litre of water; stronger solutions cannot be kept longer than a few hours. Spectral analysis shows that the liquid is a solution, and does not contain suspended particles. W. H. G.

SIMPLE, EFFECTIVE, INEXPENSIVE AND SAFE ARTIFICIAL LIGHT FOR INSTANTANEOUS PHOTOGRAPHY.—Dr. Piffard, of New York, seems to have succeeded in producing a really practicable artificial illumination for photographic purposes. It is characterized by intense actinism, extreme simplicity in production, perfect controllability, freedom from danger, and inexpensiveness, as well as absence of some of the most objectionable features of artificial lights for this purpose. The basis is magnesium in fine powder, which is deflagrated with some suitable mixture, producing a highly actinic flash. More than twenty years ago, instantaneous effects were produced in this way by J. T. Taylor, on collodion plates, and, more recently, Gaedicke and Mieth, of Germany, have patented a mixture of the kind, which leaves nothing to be desired as to effectiveness, but which, like the other, is not adapted to very general use, because of a liability to spontaneous ignition and the unpleasant and injurious character of some of the products of combustion. Dr. Piffard found that a mixture of ordinary gunpowder (one part) with magnesium powder (three parts) ignited in an open space, gave a light of the desired quality, and that even the flash of a pistol loaded with the mixture answered for the production of negatives on gelatine plates He finds it preferable, in most cases, to sprinkle the magnesium powder on a tuft of ordinary gun-cotton, on a metallic plate, and ignite it with a match; ten to fifteen grains of magnesium powder upon seven or eight grains of gun-cotton being sufficient for a single portrait. As might be expected, portraits by light from so large a surface are characterized by a softness unobtainable by other artificial illuminants. C. F. H.

BROMIDE ENLARGEMENTS FOR PREPARING SKETCHES FOR PHOTO-ENGRAVING.—It is proposed by F. C. Beach to use enlargements on bromide paper direct from the negative to assist the artist in preparing sketches in black ink, of any desired size, for photo-engraving in place of the ordinary chloride prints which must generally be first employed for making a negative of suitable size. The latter have been employed because they are readily bleached, so as to leave the black ink lines on a white ground, by bichloride of mercury. Mr. Beach has found that prints on bromide paper, fixed or unfixed, can be effectually and easily bleached out in about five minutes by immersion in the following solution, the bleaching action being assisted by movement of the solution. The alcohol in the formula is added to prevent the ink from spreading. Solution of bromide of copper is first prepared by mixing a solution of bromide of potassium 120 grains in four ounces of water, with a solution of sulphate of copper, 120 grains in four ounces of water, and the bleaching solution by using:

Bromide of copper solution	½ oz.
Hyposulphite of soda	100 grains.
Alcohol	1 oz.
Water	2 oz.

C. F. H.

The analytical tables for the qualitative examination of the artificial dye colors of commerce, recently published by

The analytical tables for the qualitative examination of the artificial dye colors of commerce, recently published by Weingärtner, have been enlarged and re-stated by G. Zetter (*Ber. Œsterr. G., 1887-89*) as follows:

I.—*Artificial Dyestuffs Soluble in Water.*

The aqueous solution gives a precipitate with the tannin reagent (25 tannin, 25 acetate of soda, and 250 water).

A.—Basic Dyestuffs.

The aqueous solution is reduced with zinc dust and hydrochloric acid, neutralized, put upon filter paper and gently warmed, when—

The original color reappears.					The original color does not reappear.
Red.	**Yellow or Orange.**	**Green.**	**Blue.**	**Violet.**	
Fuchsine. H_2SO_4 dissolves with yellowish-brown color. *Neutral Red.* H_2SO_4 dissolves with brownish-green color. *Safranine.* H_2SO_4 dissolves with green color.	*Phosphine.* With alkalies in aqueous solution, yellow precipitate, which dissolves in ether with yellow color, fluorescing strongly green. *Flavaniline.* Similar precipitate, with alkalies, soluble, however, in ether without color but with blue fluorescence.	*Malachite Green.* Ammonia produces a rose-red or gray precipitate; H_2SO_4 colors it yellow on dilution. *Brilliant Green.* Ammonia produces no, or very little, precipitate; H_2SO_4 colors it yellow, on dilution slowly becoming green. *Methyl Green.* Ammonia decolorizes it, without a trace of precipitate; H_2SO_4 colors it yellow.	*Methylene Blue.* Caustic soda precipitates it violet-black; H_2SO_4 colors it grass-green. *New Blue, B and D.* Caustic soda precipitates it brownish-black. *Bleu Nouveau.* Hot solution, violet; cold solution, green; caustic soda precipitates it brownish-red. *Muscarin.* Tannin gives an indigo-blue precipitate; caustic soda precipitates it reddish-brown.	*Methyl Violet.* (Hofmann's Violet.) H_2SO_4 yellow color, on dilution green, passing into blue-violet. *Neutral Violet.* H_2SO_4 produces dirty violet color; on dilution, blue. *Mauveine.* (Rosolan.) H_2SO_4 produces gray color; on dilution, sky-blue, passing into reddish-violet. *Amethyst.* (Fuchsia Giroflée.) H_2SO_4 produces green color; on dilution, blue. *Crystal Violet.* H_2SO_4 produces orange color, unchanged on dilution.	*Auramine.* Yellow, alkalies precipitate it white and milky; hot H_2SO_4 decolorizes it slowly. *Chrysoidine.* Orange on wool; H_2SO_4 dissolves it with yellowish-brown color. *Vesuvine.* Brownish-orange on wool; H_2SO_4 produces Havanna-brown color. *Victoria Blue.* H_2SO_4 colors it reddish-brown and then greenish-blue.

The aqueous solution does not yield a precipitate with the tannin reagent.

B.—Acid Dyestuffs.

The aqueous solution is reduced with zinc dust and hydrochloric acid.

The solution is decolorized; it is then neutralized, put upon filter paper and gently warmed, when—					The color of the solution does not disappear, but changes into a brownish-red shade. The color of the ammoniacal solution appears when put on paper.
The original color reappears. The aqueous solution is acidified with HCl and treated with ether.		The original color does not reappear. The dyestuff is heated on platinum foil.			
The ether is colored.	**The ether is not colored.**	**Deflagrates without colored fumes.**	**The dyestuffs burn slowly, reddish-brown fumes forming or deflagrates easily, with formation of reddish-brown fumes.**		
Phthaleïns. *Eosine.* Yellow with H_2SO_4. On heating HBr. vapors given off; HCl precipitates the aqueous solution orange. *Safrosine* (Scarlet). Golden yellow, with H_2SO_4. On heating HBr. vapors given off; HCl precipitates brown. *Phloxine.* Golden yellow, with H_2SO_4. HBr. vapors on heating; HCl precipitates flesh-colored. *Rose Bengale.* No fluorescence. With H_2SO_4 orange color; Iodine given off on heating. *Uranine-Chrysoline.* Solution is brownish-yellow. HCl decolorizes it with formation of a brown precipitate. *Coralline-Aurin.* Solution eosine-red. HCl gives a yellow precipitate. On heating, neither Br. or I. given off.	Sulphonated Rosaniline derivatives. *Acid Magenta.* Aqueous solution, bluish-red; H_2SO_4 solution yellow; on dilution, red. *Helvetia Green.* (Acid Green.) Aqueous solution, light green; alkalies decolorize it. *Alkali Blue.*—B — 6 B. Alkalies decolorize it. *China Blue.* Aqueous solution, blue; alkalies do not change it. *Acid Violet.* Aqueous solution, violet; ammonia decolorizes it; H_2SO_4 colors it orange; on dilution becoming greenish-blue violet. *Induline-Nigrosine.* Aqueous solution, violet, gray; HCl precipitates it bluish; ammonia, reddish-violet.	Nitro-phenols. *Picric Acid.* Aqueous solution, greenish-yellow; alkalies change it to dark-yellow; HCl produces no precipitate; deflagrates only mixed with soda. *Martius' Yellow.* HCl produces yellowish-white precipitate, soluble in ether. *Naphthol Yellow.*—S. HCl produces no precipitate, insoluble in ether. *Aurantia.* Aqueous solution concentrated red, dilute yellow; alkalies in excess precipitate it dark-red.	A dye-test upon unmordanted cotton fibre is—		Anthracene derivatives. *Alizarine.*—S. Aqueous solution, brownish-yellow; ammoniacal solution, fuchsine-red. *Cœrulein.*—S. Aqueous solution, brown-olive; ammoniacal solution, green. *Alizarine Blue.*—S. Aqueous solution, brown-red; ammoniacal solution, greenish-blue.
			Fast to soaping.	**Not fast to soaping.**	
			Benzidine-Azo Co'ors. *Congo Red.* Aqueous solution, red; blue, with HCl. *Benzo-purpurine.* Aqueous solution, orange; HCl and concentrated H_2SO_4 precipitate brown. *Azo Blue.* Aqueous solution, blue-violet; alkalies produce blood-red solution. *Erythrosine.* Aqueous solution, bluish-red; on heating iodine sublimes.	Azo Dyestuffs. *True Yellow.*—R. and G. H_2SO_4 turns yellow. *Diphenylamine Yellow.* (Tropæolin oo.) H_2SO_4 turns violet. *Azo Flavine.* H_2SO_4 turns red. *Methyl and Ethyl Orange.* H_2SO_4 turns yellow. *Yellow N. Poirrier.* H_2SO_4 turns blue-green. *Luteoline.* H_2SO_4 turns yellowish-green. *Tropæolin o.* H_2SO_4 turns brown-orange. *Mandarin.* H_2SO_4 turns carmine-red. *Biebrich Scarlet.* H_2SO_4 turns green.	

The aqueous solution is reduced with zinc dust and hydrochloric acid.

The solution is decolorized; it is then neutralized, put upon filter paper and gently warmed, when—

The original color reappears. The aqueous solution is acidified with HCl and treated with ether.

The ether is colored.

Phthaleïns.

Eosine.

Yellow with H_2SO_4. On heating HBr. vapors given off; HCl precipitates the aqueous solution orange.

Safrosine (Scarlet).

Golden yellow, with H_2SO_4. On heating HBr. vapors given off; HCl precipitates brown.

Phloxine.

Golden yellow, with H_2SO_4. HBr. vapors on heating; HCl precipitates flesh-colored.

Rose Bengale.

No fluorescence. With H_2SO_4 orange color; Iodine given off on heating.

Uranine-Chrysoline.

Solution is brownish-yellow. HCl decolorizes it with formation of a brown precipitate.

Coralline-Aurin.

Solution eosine-red. HCl gives a yellow precipitate. On heating, neither Br. or I. given off.

The ether is not colored.

Sulphonated Rosaniline derivatives.

Acid Magenta.

Aqueous solution, bluish-red; H_2SO_4 solution yellow; on dilution, red.

Helvetia Green. (Acid Green.)

Aqueous solution, light green; alkalies decolorize it.

Alkali Blue.—B — 6 B.

Alkalies decolorize it.

China Blue.

Aqueous solution, blue; alkalies do not change it.

Acid Violet.

Aqueous solution, violet; ammonia decolorizes it; H_2SO_4 colors it orange; on dilution becoming greenish-blue violet.

Induline-Nigrosine.

Aqueous solution, violet, gray; HCl precipitates it bluish; ammonia, reddish-violet.

The original color does not reappear. The dyestuff is heated on platinum foil.

Deflagrates without colored fumes.

Nitro-phenols.

Picric Acid.

Aqueous solution, greenish-yellow; alkalies change it to dark-yellow; HCl produces no precipitate; deflagrates only mixed with soda.

Martius' Yellow.

HCl produces yellowish-white precipitate, soluble in ether.

Naphthol Yellow.—S.

HCl produces no precipitate, insoluble in ether.

Aurantia.

Aqueous solution concentrated red, dilute yellow; alkalies in excess precipitate it dark-red.

The dyestuffs burn slowly, reddish-brown fumes forming or deflagrates easily, with formation of reddish-brown fumes.

A dye-test upon unmordanted cotton fibre is—

Fast to soaping.

Benzidine-Azo Colors.

Congo Red.

Aqueous solution, red; blue, with HCl.

Benzo-purpurine.

Aqueous solution, orange; HCl and concentrated H_2SO_4 precipitate brown.

Azo Blue.

Aqueous solution, blue-violet; alkalies produce blood-red solution.

Erythrosine.

Aqueous solution, bluish-red; on heating iodine sublimes.

Not fast to soaping.

Azo Dyestuffs.

True Yellow.—R. and G.

H_2SO_4 turns yellow.

Diphenylamine Yellow. (Tropæolin oo.)

H_2SO_4 turns violet.

Azo Flavine.

H_2SO_4 turns red.

Methyl and Ethyl Orange.

H_2SO_4 turns yellow.

Yellow N. Poirrier.

H_2SO_4 turns blue-green.

Lutcoline.

H_2SO_4 turns yellowish-green.

Tropæolin o.

H_2SO_4 turns brown-orange.

Mandarin.

H_2SO_4 turns carmine-red.

Biebrich Scarlet.

H_2SO_4 turns green.

Crocëin Scarlet.

H_2SO_4 turns indigo-blue.

Xylidine Ponceau.

H_2SO_4 turns violet.

The color of the solution does not disappear, but changes into a brownish-red shade. The color of the ammoniacal solution appears when put on paper.

Anthracene derivatives.

Alizarine.—S.

Aqueous solution, brownish-yellow; ammoniacal solution, fuchsine-red.

Cærulein.—S.

Aqueous solution, brown-olive; ammoniacal solution, green.

Alizarine Blue.—S.

Aqueous solution, brown-red; ammoniacal solution, greenish-blue.

gives a yellow precipitate. On heating, neither Br. or I. given off.				*Biebrich Scarlet.* H_2SO_4 turns green. *Crocëin Scarlet.* H_2SO_4 turns indigo-blue. *Xylidine Ponceau.* H_2SO_4 turns violet. *Crocëin-Scarlet.*—7B. H_2SO_4 turns blue. *Ponceau.*—R. 4R. and G. H_2SO_4 turns eosin-red. *Coccin.* H_2SO_4 turns fuchsine-red. *Roccelin.* H_2SO_4 turns violet. *Bordeaux.*—G. and R. H_2SO_4 turns blue.

Artificial Dyestuffs Insoluble in Water.

Soluble in 5 per cent. caustic soda solution.		Insoluble in 5 per cent. caustic soda solution.				
The alkaline solution is filtered, reduced with zinc dust and heat, and put upon filter-paper. The color of the alkaline solution—		Soluble in 70 per cent. alcohol.				Insoluble.
		The alcoholic solution does not fluoresce.		The alcoholic solution does fluoresce.		
Reappears.	Does not reappear.	Becomes reddish-brown with 33 per cent. soda solution.	No change with 33 per cent. soda solution.	Fluorescence disappears with 33 per cent. soda solution.	Fluorescence does not disappear with 33 per cent. soda solution.	
Gallocyanine. Soda solution, violet; H_2SO_4 solution, blue. *Gallëine.* H_2SO_4 solution, indigo-blue. *Cærulëine.* Soda solution, green; H_2SO_4 solution, green. *Galleflavine.* Soda solution, yellow; H_2SO_4 solution, yellow.	*Canarine.* Soda solution, yellow; insoluble in H_2SO_4. *Alizarine.* Soda solution, blue-violet; heated with zinc dust becomes red. *Anthra and Flavo-purpurine.* Soda solution, fuchsine-red. *Chrysamine.* Soda solution, orange; H_2SO_4 solution, fuchsine-red. *Nitro-Alizarine.* Soda solution, red; reduced with zinc dust and put on filter-paper, indigo-blue spots. *Alizarine-brown.* Soda solution, brown-olive; H_2SO_4 solution, brown-red. *Alizarine-blue.* Difficultly soluble in soda, with green color; on filter-paper, dirty-violet spots.	*Induline-Nigrosine.* Alcoholic solution, bluish-green; extracted with benzene, deep reddish-brown fluorescence. *Rosaniline or Diphenyl-amine-blue.* Alcoholic solution, deep-blue; with HCl, greenish; no fluorescence with benzene.	*Indophenol.* Alcoholic solution becomes reddish; brown with HCl.	*Magdala-red.* Alcoholic solution is bluish-red, with cinnabar fluorescence.	*Primrose.* Alcoholic solution is bluish-red, with yellow fluorescence. *Cyanosine.* Alcoholic solution is bluish-red, with brick-red fluorescence.	*Indigo.* Powdered and reduced with zinc dust and NH_3 gives yellow solution, which, put on filter-paper, yields bluish spots.

S. P. S.

A SIMPLIFIED PLATINOTYPE PROCESS, just published by Captain Pizzighelli, by which prints are produced directly in the printing frame without subsequent development, has rendered that process one of the simplest printing processes, and may do much to bring it into competition with the silver process, especially as it seems to afford either a glossy or matt surface. This is accomplished by adding to the sensitizing solution some vehicular substance, in practice gum-arabic or arrow-root, which prevents the penetration of the paper by the solution, and at the same time some one of the usual developing agents, as ammonium or sodium ferric oxalate, together with the chloro-platinite of potassium. Reduction of the platinum salt thus takes place in the printing frame, and, as the picture becomes visible, the exposure can be judged as accurately as in the silver process, whilst all the subsequent operations of the silver process of washings, toning, fixing, etc., are replaced by simple washing, first in acidulated water and then in ordinary water for ten or fifteen minutes; which completes the process. The sheet rubber or waxed paper, to prevent effect of moisture, is also unnecessary. Several modifications in working are practicable. The prints may be underexposed and laid aside in the dark for several hours, to be brought up by a continuating action which takes place, or they may be still more underexposed and be developed as usual.

Time is wanting to permit definite statement as to the keeping qualities of the paper, but samples have remained unchanged for several weeks.

C. F. H.

THE IDENTITY OF INOSITE AND DAMBOSE. Maquenne (*Bul. Soc. Chim.*, **48**, 162).—In 1868, Aimé Girard discovered among the products of the action of hydriodic acid on the dambonite, obtained from crude Gaboon caoutchouc, a saccharine substance having the composition $C^6 H^{12} O^6$, to which he gave the name dambose. The properties of this substance closely resembling those of inosite, of which the preparation from walnut leaves and the constitution had been studied by the author (this JOURNAL, cxxiii, 498), the relations of the two compounds suggested a closer investigation. The dambose was prepared by Girard's method (*Comptes Rendus*, **67**, 820), and in its properties and those of its acetyl derivatives was found to be identical with inosite; the latter substance, therefore, seems to be widely disseminated in vegetable organisms. Dambonite is dimethyl inosite, and the name dambose must be abandoned for the sugar derived from it. The abundance of dambonite in Gaboon caoutchouc naturally suggests the latter substance as the most profitable source of inosite.

W. H. G.

ON A NEW CLASS OF VOLTAIC COMBINATIONS, IN WHICH OXIDIZABLE METALS ARE REPLACED BY ALTERABLE SOLUTIONS. C. R. Alder Wright. (*Jour. Chem. Soc.*, **51**, 672).—The author has made experiments in the construction of batteries in which platinum or carbon plates are immersed in communicating fluids capable of undergoing chemical reaction. In all cases, the plate immersed in the oxidizable fluid acquires the lower potential, the other the higher potential. The liquids are prevented from mixing by the interposition of some other liquid, through which the two must diffuse, the intermediate

reagent being placed in the bend of a U-tube, the limbs of which contain the other two, or in a beaker placed between two beakers containing the others, and communicating with them by means of cotton or asbestos wicks. Among the liquids mentioned, are: (A.) Solution of sulphurous acid opposed to potassium chromate and sulphuric acid solution, with sulphuric acid intermediate; this cell develops about 1·5 volt, and is constant. (B.) Sodium sulphite solution opposed to potassium permanganate rendered alkaline with potassium hydroxide. (C.) Chromium sesquioxide dissolved in sodium hydroxide, opposed to potassium bichromate and sulphuric acid solution. (D.) Potassium ferrocyanide opposed to potassium bichromate and sulphuric acid. (E.) Lead oxide dissolved in sodium hydroxide, opposed to an alkaline permanganate, hypochlorite or hypobromite. W. H. G.

THE PREPARATION OF CHLORINE, SULPHUR DIOXIDE AND OXYGEN IN KIPP'S APPARATUS.—Clemens Winckler (*Berl. Ber.*, **20,** 184) recommends the preparation of chlorine from chlorinated lime and hydrochloric acid in Kipp's apparatus. The chlorinated lime is first mixed with about one-fourth its weight of dry plaster of Paris, and the mixture is moistened and compressed. It is then cut into small cubes, and is ready for use. The hydrochloric acid, S. G. 1·124, is diluted with an equal volume of water.

G. Neumann (*loc. cit.* 1584) finds that sulphur dioxide may be readily prepared in the same manner, the materials being strong sulphuric acid and cubes composed of a mixture of three parts calcium sulphite to one part of plaster. For the preparation of oxygen, the cubes are made of two parts barium dioxide, one part manganese dioxide and one part plaster; the liquid is hydrochloric acid, S. G. 1·12, diluted with an equal volume of water; the oxygen will contain traces of chlorine, and should be washed through alkaline hydroxide solution. The cubes of the various substances are prepared and sold by Trommsdorff of Erfurt. W. H. G.

THE BOILING POINT OF OZONE AND THE FREEZING POINT OF ETHYLENE. K. Olszewski (*Monat. für Chem.*, **8,** 70).—Ozonized oxygen was led into a narrow tube cooled to — 181°·4 by boiling oxygen under ordinary pressure. The ozone then condensed to a dark blue liquid, and the tube containing it was placed in ethylene cooled by evaporation to about — 140°. It began to evaporate when the ethylene was near its boiling point, and the temperature of the ethylene when the ozone began to boil was — 106°. Liquid ozone is instantly decomposed with explosion by contact with combustible gases.

Ethylene cooled by boiling oxygen under ordinary pressure solidifies to a white, crystalline and almost transparent mass, which melts at about — 169°. W. H. G.

THE BLUE IODIDE OF STARCH. F. Mylinus (*Berl. Ber.*, **20,** 688).—The blue color developed by the action of iodine on starch has been believed to be a simple addition product, or merely starch dyed by iodine. The author has examined the substance and determined the ratio of iodine to starch. The iodide of starch may be prepared from a clear starch solution, by the addition of a solution of iodine in potassium iodide; the blue liquid may then

be filtered without any solid matter separating. When sulphuric acid is added, the iodide of starch is thrown down and may be easily separated by filtration, and washed with water. The analysis of the substance dried in vacuum gave 18·47 per cent. iodine. Since the compound is very unstable, it was again analyzed without drying, as follows: a few cubic centimetres of the moist substance was treated with sulphurous acid, the fluid then becomes colorless, and after standing some hours, alcohol was added to precipitate all the starch. The latter was collected on a filter, dried at 120° and weighed; the filtrate contains hydriodic acid in which the iodine is estimated. Two analyses gave 19 65 and 19·69 per cent. of iodine; repetition of the method always gave between seventeen and nineteen per cent. The formula $(C^{24} H^{40} O^{20} I)^4 HI$ would require 19·67 per cent., and this appears to the author the most probable formula.

Iodide of starch contains a hydrogen atom, which is replaceable by metal, and the metallic substitution compounds are formed when a solution of iodine in a metallic iodide is used in the preparation of the blue compound. Some of these compounds, as those of sodium and potassium, are soluble in water; others, such as the barium and zinc compounds, are entirely insoluble. Analysis of the barium compound is in accord with the formula $[(C^{24} H^{40} O^{20} I)^4 I^4]^2 Ba$. W. H. G.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 21, 1887.*]

HALL OF THE INSTITUTE, December 21, 1887.

JOSEPH M. WILSON, President, in the Chair.

Present, 143 members and twenty-six visitors.

New members, elected since last meeting, seventeen.

The following nominations for officers, managers, and members of the Committee on Science and the Arts were made.

For *President* (to serve one year), ... JOSEPH M. WILSON.
For *Vice-President* (to serve three years), . . . W. P. TATHAM.
For *Secretary* (to serve one year), ... WM. H. WAHL.
For *Treasurer* (to serve one year), ... SAMUEL SARTAIN.
For *Auditor* (to serve three years), ... LEWIS S. WARE.

For *Managers* (to serve three years):

WILLIAM SELLERS, CYRUS CHAMBERS, JR., HUGO BILGRAM,
G. MORGAN ELDRIDGE, HENRY R. HEYL, CHAS. HARE HUTCHINSON,
SAMUEL R. MARSHALL, CHAS. E. RONALDSON,

Members of the Committee on Science and the Arts (to serve three years): J. M. Emanuel, C. W. Howard, Prof. L. B. Hall, John Haug, Henry R. Heyl, Fred E. Ives, W. M. McAllister, Philip Pistor, H. Pemberton, Jr., Thomas Shaw, Louis H. Spellier, Prof. S. P. Sadtler, T. C. Search, W. Rodman Wharton, Otto C. Wolf, Moses G. Wilder.

Mr. GEORGE S. STRONG, of New York, presented a second communication on the "Strong Locomotive," describing some further improvements in the details of its construction, and giving a summary of tests of its efficiency made by Mr. E. D. LEAVITT. The paper has been referred to the Committee on Publications.

Mr. FRED E. IVES gave a brief historical sketch of the invention of what is known as the "Ether-Oxygen Lime Light." He described the several methods and forms of apparatus that had been suggested and put in practice for dispensing with the hydrogen element in employing the lime light for projection, and explained and exhibited an improved form of apparatus for carburetting oxygen, which he had devised. An abstract of Mr. Ives' remarks appears elsewhere in this impression of the JOURNAL.

Mr. WM. S. COOPER, by invitation, described and exhibited specimens of improved sanitary appliances of his invention and manufacture.

Mr. W. CURTIS TAYLOR showed, with the aid of the lantern, a photograph of a group of people, which was rendered most interesting from the fact that portions of the background—the frame of a door, the wicker-work of a chair, etc.—appeared in curious fashion upon the images of certain persons in the group.

The Secretary, in his monthly report, referred to the recent trials on a section of the Pennsylvania Railroad of the Westinghouse power brake for freight trains, and gave an account of the tests made with it, which appeared satisfactorily to demonstrate the great value of the Westinghouse system for the freight service of railways. The Secretary described and exhibited the operation of a life-saving apparatus devised by Mr. J. S. BADIA, and several useful products manufactured from the waste of oil-cloth, by processes invented by Mr. W. L. LANCE.

Considerable discussion was called forth by the offer of a resolution embodying a suggestion to erect an additional story on the Hall, in order to meet the pressing need for more space to properly accommodate the constant accessions to the library. The resolution was not favorably received.

Adjourned.

WM. H. WAHL, *Secretary*.

LIST OF BOOKS

PRESENTED TO THE LIBRARY.

(*Continued.*)

Cornell University Experiment Station. Third Annual Report. 1883-84, and 1884-5. Presented by the Director.

Cornell University Register. 1885-86. Ithaca, N. Y. Presented by the University.

Corthell, E. L. Discussion of the Paper of E. Sweet, the Radical Enlargement of the Erie Canal. American Society of Civil Engineers. Presented by the Author.

Corthell, E. L. The Interoceanic Problem, and its Scientific Solution. An address. August 26, 1885. Presented by the Author.

Council, Common, of Philadelphia. Journal. October 1884 to April, 1886. Presented by the President of Common Council.

Council, Select, of Philadelphia. Journal. 1884 to 1885. Presented by the President of Select Council.

Councils of Philadelphia. Ordinances. 1884 and 1885. Presented by the Councils.

Courtonne, E. Manuel de la langue Nèo-Latine. Nice, 1886. Presented by the Author.

Cushing, L. S. Rules of Proceeding and Debate in Deliberative Assemblies. Boston, 1874. Presented by Mrs. Wm. B. Rogers.

Dahlstrom, Karl P. The Fireman's Guide; a Hand-book on the Care of Boilers. New York: E. & F. N. Spon. 1885. Presented by the Publishers.

Dana, J. D. System of Mineralogy. New York, 1844. Presented by Mrs. Wm. B. Rogers.

Davenport Academy of Natural Sciences. Elephant Pipes and Inscribed Tablets. By Chas. E. Putnam. Presented by the Academy.

Davenport Academy of Natural Sciences. Proceedings. Vol. 5. Davenport, 1886. Presented by the Academy.

Davis's Magnetism. Book of Telegraph and Electricity. Boston, 1851. Presented by Mrs. Wm. B. Rogers.

Davis's Magnetism. Boston, 1842. Presented by Mrs. Wm. B. Rogers.

Day, S. Historical Collections of the State of Pennsylvania. Philadelphia, N. D. Presented by Mr. Chas. J. Shain.

De Candolle, A. P. Théorie élémentaire de la Botanique. Paris, 1819. Presented by Mrs. Wm. B. Rogers.

Delaunay, C. V. L'Électricité. Paris, 1809. Presented by Mrs. Wm. B. Rogers.

Denver Chamber of Commerce and Board of Trade. First Annual Report for 1883. Presented by Frank Hall, Secretary.

Department of Agriculture. U. S. Bureau of Animal Industry. First and Second Annual Reports for 1884–85. Washington.

Department of Agriculture, Div. of Chem. Bul. No. 7 and 12. Washington, 1885–86.

Department of Agriculture. Report No. 23. Report on Condition of Crops, Yield of Grain per acre, etc. Oct. 1885. Washington.

Department of Agriculture. Reports of the Statistician. Nos. 21, 22, 26 and 27, 28, 32 and 33. Washington, 1885-86.

Department of Agriculture. U. S. Report of the Commissioner, 1885. Washington.

Department of Agriculture. U. S. Special Reports. Nos. 2, 4, 5, 6, 7, 8, 10, 16 and 17 of Vol. 1 and Vols. 7 to 12 inclusive. Washington, 1877-86. And special reports on Soils of Louisiana and Maine. Presented by the Department.

Department of State. Letter from the Secretary with report of Electrical Conference at Philadelphia, 1884. Washington, 1886.

Department of State. U. S. Reports from the Consuls of the United States on the Commerce, etc., of their Consular Districts. Nos. 53 and 53½. June 1885. Washington. Presented by the Department.

Descriptive Catalogue of Government Publications of the United States. 1774-1881. Washington, 1885. Presented by Hon. Chas. O'Neill, M.C.

Detroit. Annual reports of the Board of Water Commissioners for 1881 to 1885. Presented by the Board.

Dick, Thos. The Practical Astronomer. Philadelphia, 1848. Presented by Mrs. Wm. B. Rogers.

Dick Thos. The Solar System. Philadelphia, 1848. Presented by Mrs. Wm. B. Rogers.

Dictionary of Chemical and Philosophical Apparatus. London, 1824. Presented by Mrs. Wm. B. Rogers.

Dictionary of Science, Literature, and Art. Edited by W. T. Brande. New York. 1856. Presented by Mrs. Wm. B. Rogers.

Directory of Select and popular Quotations. Presented by Mrs. Wm. B. Rogers.

District of Columbia. Report of the Health Officer for 1885. Washington. 1889. Presented by the Health Officer.

Donovan, M. Galvanism. Dublin, 1816. Presented by Mrs. Wm. B. Rogers.

Drains and Sewers, Sewage and Manure. Abridgments of Specifications Relating to. A. D. 1867–1876. Part 2. London, 1885. Presented by the Commissioners.

Draper, D. Pneumonia and Ozone. A Paper on.
Presented by the Author

Draper, John Wm. Scientific Memoirs. New York, 1878.
Presented by Mrs. Wm. B. Rogers.

Dudley Observatory. Statement of the Trustees and the Scientific Council. Albany, 1858. Presented by A. Whitney & Sons.

Dunglison, R. Dictionary of Medical Science. Reo & Earl. Philadelphia, 1860. Presented by Mrs. Wm. B. Rogers.

Dunglison, R. Human Physiology. Vol. 2. Philadelphia, 1844.
Presented by Mrs. Wm. B. Rogers.

Eagle Lock Company. Illustrated Catalogue and Price List. Vol. 13. Hartford. Presented by the Company.

Eastern State Penitentiary of Pennsylvania. Sixth Annual Report of the Inspectors. Philadelphia, 1834. Presented by the Inspectors.

East Tennessee, Virginia and Georgia Railroad Company. Annual Reports for 1880-81 and 1884. Knoxville. Presented by the Company.

Eclipse of the Sun, Reports of Observations of. August 7, 1869. Made by Parties under the General Direction of Prof. J. H. C. Coffin. Washington. Presented by the Navy Department.

Edler, Robt. Acetophenon Derivate. Inaugural-Dissertation. Vorgelegt von Robert Edler. Karlsruhe, 1884. Presented by G. Braun, Publisher.

Erodnitzky, B. Ueber das Elsässer Petroleum. Karlsruhe. Braun. 1884.
Presented by the Publisher.

Elderhorst, Wm. Manual of Blow-pipe Analysis and Determinative Mineralogy. Philadelphia. Presented by Mrs. Wm. B. Rogers.

Elderhorst's Manual of Qualitative Blow-pipe Analysis. Philadelphia.
Presented by Mrs. Wm. B. Rogers.

Electrical Conference at Philadelphia. Report. September, 1884. Washington, 1886. Presented by Prof. L. M. Snyder.

Electrical Department of Philadelphia. Annual Reports for 1884-85.
Presented by the Chief of the Department.

Engine, Boiler and Employer's Liability Insurance Company. Chief Engineer's Report for 1885. Presented by the Company.

Engineer Department, U. S. Annual Reports of Chief of Engineer for 1885. Washington, 1886. Presented by the Government.

Engineers' Society of Western Pennsylvania. Paper on (1) Conveyance of Gas; (2) Standard Rail Sections and Fish-Bar joints; (3) Torsion Balance.
Presented by the Society.

Entomological Commission. U. S. Third Report. Washington, 1883.
Presented by the Department of Agriculture.

Escola de Minas de Ouro Preto-Annaes da. No. 4. 1885.
Presented by the School.

Estados Unidos Mexicanos. Documents. Nos. 14 and 15. 1886.
Presented by the Office through the Consul.

Fall River, Mass. Board of Health. Annual Report for 1885.
Presented by the Board.

Fall River, Mass. Twelfth Annual Report of the Watuppa Water Board. January, 1886. Presented by the Board.

Faraday, M. Researches in Electricity. Vol. 3. London, 1855. Presented by Mrs. Wm. B. Rogers.

Faught vs. Charlton. Interference. Couplings for Shafting. Philadelphia, N. D. Presented by Dr. W. H. Wahl.

Faust, E. D. Sketch of Medical Chemistry. Columbia, 1828. Presented by Mrs. Wm. B. Rogers.

Fibre and Fabric. A Weekly Journal published in Boston. Presented by Wade & Co., Publishers.

Fisheries and Fishery Industry of the United States. By G. Brown Goode. Washington, 1884. Presented by the Commissioner.

Flammarion, C. Les merveilles célestes. Paris, 1867. Presented by Mrs. Wm. B. Rogers.

Foreign Relations of the United States, Papers Relating to. 1884. Washington, Government, 1885. Presented by the Department of State.

Fownes, Geo. Chemistry. New York, 1844. Presented by Mrs. Wm. B. Rogers.

Fownes, George. Elementary Chemistry. Philadelphia, 1853. Presented by Mrs. Wm. B. Rogers.

Francis, G. Chemical Experiments. Fourth Edition. London, 1847. Presented by Mrs. Wm. B. Rogers.

Francis, G. Electrical Experiments. London, 1844. Presented by Mrs. Wm. B. Rogers.

Frankland, E. Chemistry. Philadelphia, 1875. Presented by Mrs. Wm. B. Rogers.

Frankland, Edward. How to Teach Chemistry. London, 1875. Presented by Mrs. Wm. B. Rogers.

Franklin Institute. Official Catalogue of the Novelties Exhibition. Philadelphia, 1885. Presented by Burk & McFetridge, Printers and Publishers.

Frazer, Persifor. Archæan-Palæozoic Contact near Philadelphia, Pa. Salem, 1885. Presented by the Author.

Freedley, E. T. Leading Pursuits and Leading Men. Philadelphia, N. D. Presented by Chas. Bullock.

Freedley, E. T. Philadelphia and its Manufactures. Philadelphia, 1859. Presented by Whitney & Sons.

Fremin, A. R. Nouvelle Carte Physique et Routière de la France. Paris, 1867. Presented by Mrs. Wm. B. Rogers.

Fresenius, C. R. & H. Will. New Methods of Alkalimetry. London, 1843. Presented by Mrs. Wm. B. Rogers.

Fresenius, C. R. Instruction in Chemical Analysis. London, 1846. Presented by Mrs. Wm. B. Rogers.

Fresenius, C. R. System of Instruction in Quantitative Chemical Analysis. New York, Wiley & Son. 1871. Presented by Mrs. Wm. B. Rogers.

Gairdner, W. T. Medicine and Medical Education. Edinburgh, 1858. Presented by Mrs. Wm. B. Rogers.

Gall et Spurzheim. Anatomie et Physiologie du Système Nerveux en General. Atlas. Paris, 1810. Presented by Mrs. Wm. B. Rogers.

Galloway, Robt. Manual of Qualitative Analysis. Philadelphia, 1872. Presented by Mrs. Wm. B. Rogers.

Gamgee, Arthur. Text-Book of Physiological Chemistry of the Animal Body. Vol 1. London, 1880. Presented by Mrs. Wm. B. Rogers.

Ganot, A. Traité de Physique. Paris, 1868. Presented by Mrs. Wm. B Rogers.

Gardner, D. P. Medical Chemistry. Philadelphia, 1848. Presented by Mrs. Wm. B. Rogers.

Garrett, A. C. Electro-Physiology and Electro-Therapeutics. Boston, 1861. Presented by Mrs. Wm. B. Rogers.

Gas Consumers' Guide. Boston, 1871. Presented by Mrs. Wm. B. Rogers.

Gatewood, R. Report of Naval Advisory Board on Mild Steel. Washington, 1886. Presented by the Navy Department, U. S.

Geological Society, London. List of Members. November, 1885. Presented by the Society.

Geological Survey of India. Palæontologia Indica. Ser. 10. Vol. IV. Part 1. Calcutta, 1886. Presented by the Survey.

Geology of New Hampshire. Vols. 1–3 and Atlas. Concord, 1874–1878. Presented by W. H. Kimball, State Librarian.

Geological Survey of New Jersey. Maps. Sheets 1, 9, 13 and 17. Presented by Prof. G. H. Cook, State Geologist.

Geological Survey of Pennsylvania. Annual Report. 1885. Abridged, 1886. Presented by the Survey.

Geological Survey of Pennsylvania. Reports of Progress. A.A. Atlas. Eastern Middle Anthracite Field. Part 1. C. 5 Delaware. Part 1. T. 3, Huntingdon. Harrisburg, 1885. Presented by Senator F. A. Osbourn.

Geological Survey of Pennsylvania. Grand Atlases. Division 2, Part 2. Division 3, Division 4, Part 1, and Division 5, Part 1. Presented by Wm. A. Ingham, Secretary.

Georgia State Agricultural Society. Transactions of Meetings in 1883–84–85. Presented by the Society.

Germanischer Lloyd, Deutsche Gesellschaft zur Classificirung von Schiffen. Internationales Register, 1886. Presented by the Association.

Gieseler, E. A. Tidal Theory and Tidal Predictions. Philadelphia, 1885. Presented by the Author.

Godwin, Wm. Enquiry Concerning Political Justice. In 2 vols. Vol. 2. London, 1796. Presented by Mrs. Wm. B. Rogers.

Graham, Thos. Chemical Reports and Memoirs. London, 1848. Presented by Mrs. Wm. B. Rogers.

Graham, Thos. Elements of Chemistry. Philadelphia, 1843. Presented by Mrs. Wm. B. Rogers.

Graham, Thos. Elements of Chemistry. Second Edition. London, N. D. Presented by Mrs. Wm. B. Rogers.

Gramm, J. C. Der Architekt für Freunde der Schönen Baukunst. Frankfurt, 1854–58. Presented by Mr. Fred'k Graff.

Gray, Sam'l. F. The Operative Chemist. London, 1828.
Presented by Mrs. Wm. B. Rogers.

Greek and English Lexicon. Second Edition. Boston, 1829.
Presented by Mrs. Wm. B. Rogers.

Greene, Wm. H. Practical Hand-Book of Medical Chemistry. Philadelphia, 1880. Presented by Mrs. Wm. B. Rogers.

Green, Horace. A Treatise on Diseases of the Air Passages. New York, 1846. Presented by Mrs. Wm. B. Rogers.

Greenhow, T. M. Cholera. Philadelphia, 1832.
Presented by Mrs. Wm. B. Rogers.

Gregory, Wm. Chemistry. London, 1845.
Presented by Mrs. Wm. B. Rogers.

Gregory, Wm. Hand-Book of Organic Chemistry. London, 1852.
Presented by Mrs. Wm. B. Rogers.

Grier, John A. Our Silver Coinage, and its Relation to Debts and the World-wide Depression in Prices. Philadelphia, 1885.
Presented by the Author.

Griffith, R. E. Medical Botany. Philadelphia, 1847.
Presented by Mrs. Wm. B. Rogers.

Grove, W. R. Correlation of the Physical Forces. London, 1850.
Presented by Mrs. Wm. B. Rogers.

Guardians of the Poor. Annual Statements of the Accounts for 1854 to 1884. Philadelphia, 1855–85. Presented by the Board.

Guillemin, A. La Lune. Second Edition. Paris, 1868.
Presented by Mrs. Wm. B. Rogers.

Guillemin, A. Le Soleil. Second Edition. Paris, 1869.
Presented by Mrs. Wm. B. Rogers.

Gurney, G. Course of Lectures of Chemical Science. London, 1823.
Presented by Mrs. Wm. B. Rogers.

Guyot, Arnold. The Earth and Man. Lectures on Comparative Physical Geography in its Relation to the History of Mankind. Boston, 1849.
Presented by Mrs. Wm. B. Rogers.

Hance E. H. Physicians' Compend. Philadelphia, 1871.
Presented by Mrs. Wm. B. Rogers.

Harcourt & Madan. Practical Chemistry. Oxford, 1869.
Presented by Mrs. Wm. B. Rogers.

Harrison, A. W. Fragrance. A lecture delivered at Horticultural Hall May 19, 1885. Presented by the Pennsylvania Horticultural Society.

Harrison, J. P. Essays and Lectures on Medical Subjects. Philadelphia, 1835. Presented by Mrs. Wm. B. Rogers.

Hartley, F. W. Gas Measurement and Gas Meter Testing. London, 1873.
Presented by Mrs. Wm. B. Rogers.

Haupt, L. M. Harbor Studies. General Requirements, etc. 1886.
Presented by the Author.

Headland, F. W. On the Action of Medicines in the System. Philadelphia, 1870. Presented by Mrs. Wm. B. Rogers.

Henry, Wm. Elements of Experimental Chemistry. 11th Ed. Philadelphia, 1831. Presented by Mrs. Wm. B. Rogers.

Herschel, John F. W. Treatise on Astronomy. Philadelphia, 1838.
Presented by Mrs. Wm. B. Rogers.

Hichborn, P. Report on European Dock Yards. Washington, 1886.
Presented by the Navy Department.

Hillard, G. S. Six Months in Italy. In two Vols. Vol. 2. Boston, 1853.
Presented by Mrs. Wm. B. Rogers.

Hill, H. B. Lecture Notes on Qualitative Analysis. N. Y., 1874.
Presented by Mrs. Wm. B. Rogers.

Hinton, J. H. History and Topography of the United States. Vols. 1 and 2. London, 1834. Presented by Mr. Samuel H. Needles.

History of Wonderful Inventions. 2 parts in 1 Vol. New York, 1849.
Presented by Mrs. Wm. B. Rogers.

Hitchcock, Edward and Chas. H. Elementary Geology. New York, 1866.
Presented by Mrs. Wm. B. Rogers.

Hogg, J. The Microscope. Its History, Etc. London, 1854.
Presented by Mrs. Wm. B. Rogers.

Holmes & Co., W. C. Instructions for the Management of Gas Works.
Presented by Mrs. Wm. B. Rogers.

Hourly Readings. July to September, 1883. London, 1886.
Presented by the Council.

Houston, E. J. Glimpses of the International Electrical Exhibition. 1886.
Presented by the Author.

Hoskins, G. G. An Hour with a Sewer Rat. London, 1879.
Presented by F. Eisenbrey.

Howe, J. Specimen of Printing Types and Ornaments. Philadelphia, 1830.
Presented by Mrs. Wm. B. Rogers.

Hudson, N. J. Annual Reports to the Board of Health, and Vital Statistics for 1877, 1879, 1881, 1882 and 1884. Presented by the Company.

Huggins, Wm. Results of Spectrum Analysis Applied to Heavenly Bodies. London, N. D. Presented by Mrs. Wm. B. Rogers.

Hughes, R. W. The American Dollar and the Anglo-German Combination. Richmond, 1885. Presented by the Author.

Huxley, Thos. H. On the Origin of Species. New York, 1863.
Presented by Mrs. Wm. B. Rogers.

Hydro Mechanics, The Theory and Practice of. London, 1885.
Presented by Institution of Civil Engineers.

Illinois. Department of Agriculture. Transactions. Vol. 22. 1884. Springfield, 1885. Presented by the Department.

Illinois Industrial University. Twelfth Annual Report of the Board of Trustees, 1884. Presented by the Board.

Illinois. New Sectional Map of the State. By Peck and Messinger, N. Y. 1836. Presented by Mrs. Wm. B. Rogers.

Illinois State Board of Agriculture. Crop Reports for April and May, 1885. Report of Seventh Annual American Fat Stock Show. 1884. Statistical Report of the Board for June. 1885. Presented by the Board.

Illinois State Laboratory of Natural History. Bulletins Nos. 1–6. Vols. 1 to 3 and Index. Normal, Ill., 1876–1885.
Presented by Prof. S. A. Forbes.

Illustrated History of the United States Mint. Philadelphia. Geo. Evans 1884.

Imperial College of Engineering. Tokio. Reports of the Professors. 1873–77. Presented by Smithsonian Institution.

Imports and Exports of the United States. Monthly Summary Statements. Prepared under the Direction of the Chief of the Bureau of Statistics. Washington, 1885. Presented by the Chief of Bureau.

India. Geological Survey. Memoirs. Series IV, Vol. 1, Part 5. Palæontologia Indica. Series X, Vol. 3, Parts 1–6. Calcutta, 1885. Presented by the Survey.

India. Report on the Meteorology for 1883 and 1884. Calcutta, 1885–86. Presented by the Meteorological Department.

Indian Meteorological Memoirs. Vol. 2, Part 4. Calcutta, 1885. Presented by the Meteorological Department, Government of India.

Indian Affairs. Commissioner of. Annual Reports for 1870, 1872, 1884, 1885. Presented by the Commissioner.

Indiana. Third Annual Report of the State Board of Health for 1884. Indianapolis, 1885. Presented by the Board.

Indiana State Board of Agriculture. Annual Reports for 1869, 1872, 1873 and 1874. Presented by F. M. Crouse, Indianapolis, Ind.

Indianapolis, Ind. Annual Report of the Board of Health for 1885. Presented by the Board.

Institution of Civil Engineers of Ireland. Vols. 15 and 16. Dublin, 1885–86. Presented by the Institution.

Institution of Civil Engineers. London. Brief Subject Index to Vols. 59 to 82 of Minutes of Proceedings. Presented by the Institution.

Institution of Civil Engineers. London. Charter and By-Laws and List of Members. London, 1885. Presented by the Institution.

Institution of Civil Engineers. London. Heat in its Mechanical Applications. A Series of Lectures Delivered in 1883–84. London. Institution, 1885. Presented by the Institution.

Institution of Civil Engineers. Minutes of Proceedings. Vols 80 to 86. Session 1884–5–6. Presented by the Institution.

Institution of Naval Architects. Transactions. Vol. 26. London, 1885. Presented by the Institution

Instituto y Observatorio de Marina de San Fernando. Anales for 1884. Presented by the Instituto.

Insurance Company of North America. History of. Philadelphia, 1885. Presented by the President

Insurance Year-Books for 1880–1 to 1885–6. New York. The Spectator Company, 1880–85. Presented by the Company.

Interior Department. U. S. Annual Report of the Secretary for 1883–84–85. Vols. 1 and 5. Washington, 1885–86. Presented by the Secretary of the Interior.

Internal Commerce of the United States. Report by Jos. Nimmo. Washington, 1885. Presented by the Bureau of Statistics.

Iowa. Census for the Year 1885. Presented by the Secretary of State.

Iowa State Board of Health. Third Biennial Report. Des Moines, 1885.
Presented by the Board.

Jacksonville, Fla. Reports of the Trustees of the Sanitary Improvement Bonds to Council. July, 1884–July, 1885.
Presented by R. M. Ellis, Sup't.

Japanese Designs. Eight Vols. Presented by John Shinn.

Jenkin, F. Electricity and Magnetism. New York, 1879.
Presented by Mrs. Wm. B. Rogers.

Jersey City, N. J. Annual Reports of the Board of Water Commissioners for 1870, and of the Board of Public Works for 1874, 1875, 1877 and 1882.
Presented by the Board.

Johns Hopkins University Circulars. Vols. 1–4. 1879–1885. Baltimore, 1879–1885. Presented by the University.

Johnson, J. B. Manual of the Theory and Practice of Topographical Surveying. New York, John Wiley & Sons. 1885.

Johnson's English Dictionary, as Improved by Todd. Edited by J. E. Worcester. Philadelphia, 1869. Presented by Mrs. Wm. B. Rogers.

Johnston, John. Elements of Chemistry for Use of Schools. Philadelphia, 1850. Presented by Mrs. Wm. B. Rogers.

Johnston, J. Manual of Chemistry. Seventh Edition. Philadelphia, 1866.
Presented by Mrs. Wm. B. Rogers.

Johnston, J. Manual of Chemistry. Philadelphia, 1869.
Presented by Mrs. Wm. B. Rogers.

Johnston, John. Manual of Chemistry. Philadelphia, 1872.
Presented by Mrs. Wm. B. Rogers.

Johnston, J. Manual of Chemistry. Philadelphia, N. D.
Presented by Mrs. Wm. B. Rogers.

Johnston, John. Manual of Natural Philosophy. Philadelphia, 1856.
Presented by Mrs. Wm. B. Rogers.

Jones, H. B. Animal Chemistry. London, 1850.
Presented by Mrs. Wm. B. Rogers.

Jones, H. B. Animal Electricity. London, 1852.
Presented by Mrs. Wm. B. Rogers.

Jones, J. Quarantine and Sanitary Operations During 1880–1883 in Louisiana. Baton Rouge, 1884.

Journal of the Chemical Society. London. Vols. 47 and 48.

Journal of Fabrics. Vol. 7. Halifax, 1885.

Journal of Gas Lighting. Vol. 45. London, 1885.

K. K. Geographische Gesellschaft. Wien. Mittheilungen. Vol. 28. 1885.
Presented by the Society.

K. K. Geologische Reichsanstalt. Jahrbuch. Vol. 35. Parts 2, 3 and 4. Wien. 1885. Presented by the Society.

Kane, Robt. Elements of Chemistry. New York, 1850.
Presented by Mrs. Wm. B. Rogers.

Kansas Academy of Science. Transactions of 16th and 17th Annual Meetings, 1883–84. Vol. 9. Topeka, Kan., 1885.
Presented by the Academy.

Kansas City National Water Works Company. Rules and Regulations. 1885. Presented by the Works.

Kansas State Board of Agriculture. Fourth Biennial Report for 1883–84. Topeka, 1885. Presented by the Secretary of the Board.

Kansas State Board of Agriculture. Report for the Quarter ending December 31, 1885. Presented by the Secretary.

Kast, Dr. H. Ueber eine Acetophenondisulfosäure und einige Derivate derselben. Karlsruhe, Braun. 1884. Presented by the Publisher.

Kay-Shuttleworth, U. J. First Principles of Modern Chemistry. London, 1870. Presented by Mrs. Wm. B. Rogers.

Kelley, Hon. Wm. D. Speech on the National Revenue. August 3, 1886. Presented by L. S. Ware.

Kirkes & Paget's Physiology. Philadelphia, 1849. Presented by Mrs. Wm. B. Rogers.

Klein, C. H. von. Voice in Singers. Columbus, 1885 Presented by the Author.

Knapp, F. Chemical Technology. Vols. 1–3. London, 1848–51. Presented by Mrs. Wm. B. Rogers.

Knowles Steam Pump Works. Revised Illustrated Catalogue. 1885. New York. Presented by the New York Office.

Kollmyer, A. H. Chemia Coartata. Philadelphia, N. D. Presented by Mrs. Wm. B. Rogers.

Königliche Technische Hochschule zu Hannover. Programme für 1885–86. Hannover, 1885. Presented by the School.

Komnck & Dietz. Practical Manual of Chemical Analysis and Assaying. Philadelphia, 1873. Presented by Mrs. Wm. B. Rogers.

Lalande, De. Astronomie. Paris, 1764. Presented by Mrs. Wm. B. Rogers.

Lardner, D. Cabinet Cyclopædia. Treatise on Improvements in the Manufactures in Metal. Vol. 2. Iron and Steel. London, 1833. Presented by Mrs. Wm. B. Rogers.

Lardner, D. Cabinet of History. History of France, by E. E. Crowe. Vols. 1 and 2. Philadelphia, 1836. Presented by Mrs. Wm. B. Rogers.

Lardner, D. Popular Lectures on Science and Art. In two volumes. Vol. 1. New York, 1852. Presented by Mrs. Wm. B. Rogers.

Lardner, D. Popular Lectures on the Steam Engine. New York, 1828. Presented by Mrs. Wm. B. Rogers.

Lardner, D. The Steam Engine Familiarly Explained and Illustrated. Philadelphia, 1836. Presented by Mrs. Wm. B. Rogers.

Larned, E. C. In Memory of. Chicago, 1886. Presented by McClurg & Co., Publishers.

Latreille, M. Familles Naturelles du Règne Animal. Paris, 1825. Presented by Mrs. Wm. B. Rogers.

Lawrence Railroad Company. Annual Reports of the Board of Directors for 1879 to 1884. Presented by the Company.

Laws Relating to the City of Philadelphia. Philadelphia, 1860. Presented by Mrs. Wm. B. Rogers.

Lea, M. C. Manual of Photography. Philadelphia, 1868.
Presented by Mrs. Wm. B. Rogers.

Lectures on the Results of the Exhibition.. Delivered at the suggestion of H. R. H. Prince Albert. London, 1852.
Presented by Mrs. Wm. B. Rogers.

Leffmann, Henry. Chemistry. Philadelphia, 1881.
Presented by Mrs. Wm. B. Rogers.

Letters of Registration for Inventions and Improvements in Arts, etc., Granted in New South Wales. 1877–82, with Indexes.
Presented by Thos. Richards, Government Printer, for the Government.

Lewis, H. C. A Great Trap Dyke Across Southeastern Pennsylvania.
Presented by the Author.

Library Company of Philadelphia. Bulletin for July, 1876, and July, 1885.
Presented by the Company.

Liebig, J. Animal Chemistry. Cambridge, 1842.
Presented by Mrs. Wm. B. Rogers.

Liebig, Justus. Chemistry in its Application to Agriculture and Physiology. New York, 1847. Presented by Mrs. Wm. B. Rogers.

Liebig, J. Familiar Letters on Chemistry. London, Taylor et al. 1851.
Presented by Mrs. Wm. B. Rogers.

Liebig, Justus. Researches on the Chemistry of Food. London, 1847.
Presented by Mrs. Wm. B. Rogers.

Liebig, J. Researches on the Chemistry of Food, etc. Lowell, 1848.
Presented by Mrs. Wm. B. Rogers.

Life-Saving Service. U. S. Annual Report of the operations for year ending June 30, 1884. Presented by the Office.

Light-House Board. Annual Report for Fiscal Year ended June 30, 1885. Washington, Government, 1885. Presented by the Board.

Light-House Board. Index. Catalogue of the Library. Washington, 1886.
Presented by Capt. A. B. Johnson, Light-House Board.

Lincoln, Almira H. Familiar Lectures on Botany. New York, 1843.
Presented by Mrs. Wm. B. Rogers.

Lincoln, D. F. Electro-Therapeutics. Philadelphia, 1874.
Presented by Mrs. Wm. B. Rogers.

Lindley, J. Introduction to Botany. 3d Ed. London, 1839.
Presented by Mrs. Wm. B. Rogers.

Lindley, John. Natural System of Botany. London, 1836.
Presented by Mrs. Wm. B. Rogers.

Linnæan Society. Lancaster. Bulletin, Nos. 1–6.
Presented by S. M. Sener.

Literary and Philosophical Society of Manchester. Memoirs. Vol. 28. London, 1884. Presented by the Society.

Literary and Philosophical Society, Manchester. Proceedings. Vols. 23 and 24. Manchester, 1884–5. Presented by the Society.

Literary and Philosophical Society of Liverpool. Vol. 38. Session, 1883–4. London, 1884. Presented by the Society.

Liverpool Engineering Society. Annual Report for 1885.
Presented by the Society.

Lobstein, J. F. Treatise on the Structure, etc., of the Human Sympathetic Nerve. Philadelphia, 1831. Presented by Mrs. Wm. B. Rogers.

Locke, J. An Essay Concerning Human Understanding. 2 Vols. Vol. 1. N. Y., 1825. Presented by Mrs. Wm. B. Rogers.

Locomotive, The. New Series. Vol. 6. Hartford, 1885.
Presented by the Hartford Steam Boiler Inspection and Insurance Co.

Loomis, E. Treatise on Meteorology. New York, 1868.
Presented by Mrs. Wm. B. Rogers.

Loudon, J. C. Encyclopædia of Plants. London, 1841.
Presented by Mrs. Wm. B. Rogers.

Louisiana. Report of the Board of Administrators of the Charity Hospital. 1882. New Orleans, 1883.
Presented by the Librarian of the State Library.

Lowell, Mass. Annual Report of the Board of Health for 1878–83. Revised Ordinance, 1884. Clarke, E. C. Common Defects in Housedrains. Boston, 1879. Presented by the Secretary of the Board.

Löwig, C. Principles of Organic and Physiological Chemistry. Philadelphia, 1853. Presented by Mrs. Wm. B. Rogers.

Lyell, Chas. Principles of Geology. 3 Vols. Boston, 1842.
Presented by Mrs. Wm. B. Rogers.

Macbride, D. Experimental Essays. London, A. Millar. 1764.
Presented by Mrs. Wm. B. Rogers.

Macdonald, J. D. Guide to Microscopical Examination of Drinking Water. Philadelphia, 1875. Presented by Mrs. Wm. B. Rogers.

Maceuen, M. A Mosaic from Italy. Philadelphia, 1867.
Presented by Mrs. Wm. B. Rogers.

Madison, Wisconsin. Third Annual Report of the Board of Water Commissioners. 1885. Presented by J. B. Heim, Superintendent.

Maguin, A. The Bacteria. Translated by George M. Sternberg. Boston, 1880. Presented by Mrs. Wm. B. Rogers.

Manchester, N. H. First Annual Report of the Board of Health for 1885.
Presented by the Board.

Manchester, N. H. Twelfth to Fourteenth Annual Reports of the Board of Water Commissioners for 1883–85. Presented by the Board.

Mantell, G. A. Thoughts on Animalcules. London, 1846.
Presented by Mrs. Wm. B. Rogers.

Manual of British and Foreign Tramway Companies for 1878, 1879, 1880, 1882 and 1883. London, Duncan. Presented by A. Whitney & Sons.

Manual of the Practical Naturalist. Boston, 1831.
Presented by Mrs. Wm. B. Rogers.

Martinet, L. Manual of Pathology. Philadelphia, 1830.
Presented by Mrs. Wm. B. Rogers.

Massachusetts Agricultural College. Third and Fifteenth Annual Reports. Boston, 1866 and 1878. Presented by the State Librarian.

Massachusetts. Annual Reports of the Board of Railroad Commissioners for 1872, 1874, 1877, 1883, 1884 and 1885.
Presented by the State Librarian.

, 383, 357

agrams.

the Inch.

383.

Boiler Press. 165
M.E.P. 111.6

Boiler Press. 170
M.E.P. 84.1

Boiler Press. 171
M.E.P. 58.9
Speed 40.44
Rev. 206.2
Total I.H.P. 834.6

Boiler Press. 165
M.E.P. 51.8

Engine No. 357.

9

Boiler Press. 152
M.E.P. 101.2
Speed 19.47
Rev. 98.7
Total I.H.P. 762.4

10

Boiler Press. 151
M.E.P. 63.7
Speed 29.51
Rev. 149.7
Total I.H.P. 744.8

11

Boiler Press. 151
M.E.P. 48.5
Speed 36.36
Rev. 184.5
Total I.H.P. 698.6

12

Boiler Press. 137
M.E.P. 525

1. M.E.P. 55.3 lbs. I.H.P. 1869.3

4. M.E.P. 70 lbs. I.H.P. 1800.6

2. M.E.P. 60.3 lbs. I.H.P. 1800.7

5. M.E.P. 60.7 lbs. I.H.P. 1595

3. M.E.P. 64 lbs. I.H.P. 1837.3

6. M.E.P. 65.9 lbs. I.H.P. 1807.8

Indicator Diagrams for L.B. & S.C.R. for Engines Fitted with Shifting Link motion.

Scale 80 lbs. = 1"

1. D. Diagram: 42.3 Tons ore from Engine with 17×24 Cylinders 5'-3" drivers.
C. Diagram 41 from Engine with 18½×26 Cylinders. 5-0 drivers.
M.E.P. 121.8 — I.P. 135.92 — Steam Chest P. 140 — Speed. Miles. 4.

4. M.E.P. 67.40 — I.P. 409.10 — Steam Chest P. 140 — Speed. Miles. 27

2. M.E.P. 57.00 — I.P. 311.9 — Steam Chest P. 120 — Speed. Miles. 17.

5. M.E.P. 37.2 — I.P. 370.3 — Steam Chest P. 140 — Speed. Miles. 34

3. M.E.P. 47.6 — I.P. 330.24 — Steam Chest P. 135 — Speed. Miles. 28.

6. M.E.P. 19.4 — I.P. 278.8 — Steam Chest P. 130 — Speed. Miles. 39.

Indicator Diagrams, Strong Locomotive.

Indicator Diagrams, English Locomotive.

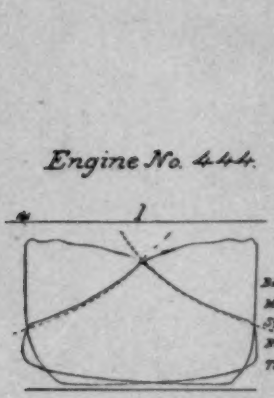
Indicator Diagrams, English Locomotive.

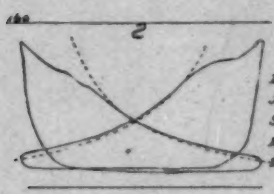
Locomotives 44

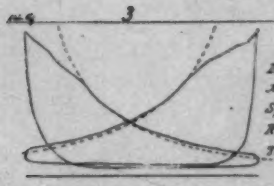
Indicator D

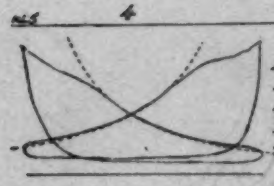
Scale: 80lbs to

Engine No. 444.

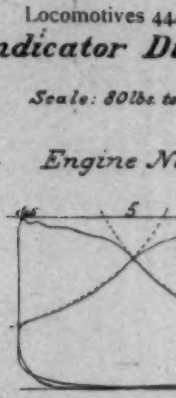


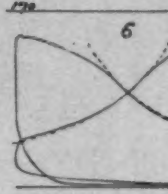


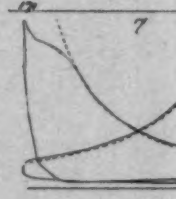


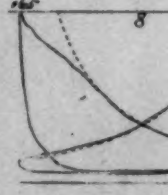


Engine N









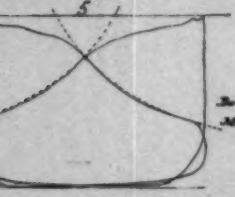
...comotives 444, 383, 357

...cator Diagrams.

...ale: 80lbs to the Inch.

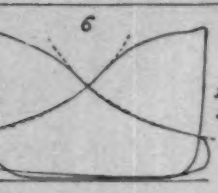
Engine No. 383.

5



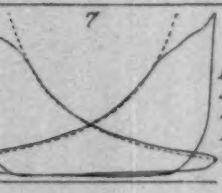
Boiler Press. 165
M.E.P. 111.6

6



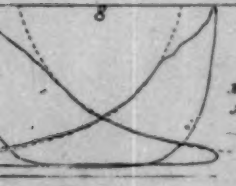
Boiler Press. 170
M.E.P. 84.1

7



Boiler Press. 171
M.E.P. 58.9
Speed 40.44
Rev. 206.2
Total I.H.P. 834.6

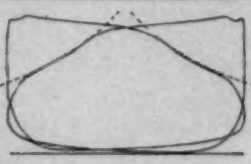
8



Boiler Press 165
M.E.P. 51.3

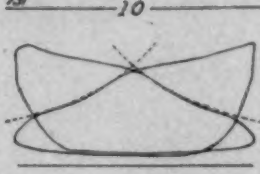
Engine No. 357.

9



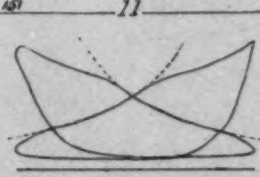
Boiler Press. 152
M.E.P. 101.2
Speed 19.45
Rev. 98.7
Total I.H.P. 762.4

10



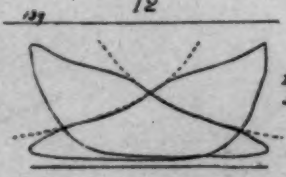
Boiler Press. 151
M.E.P. 63.7
Speed 29.51
Rev 142.7
Total I.H.P. 744.8

11



Boiler Press. 151
M.E.P. 48.5
Speed 36.36
Rev. 184.5
Total I.H.P. 698.6

12



Boiler Press. 137
M.E.P. 52.5

1.

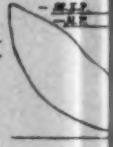
2.

3.

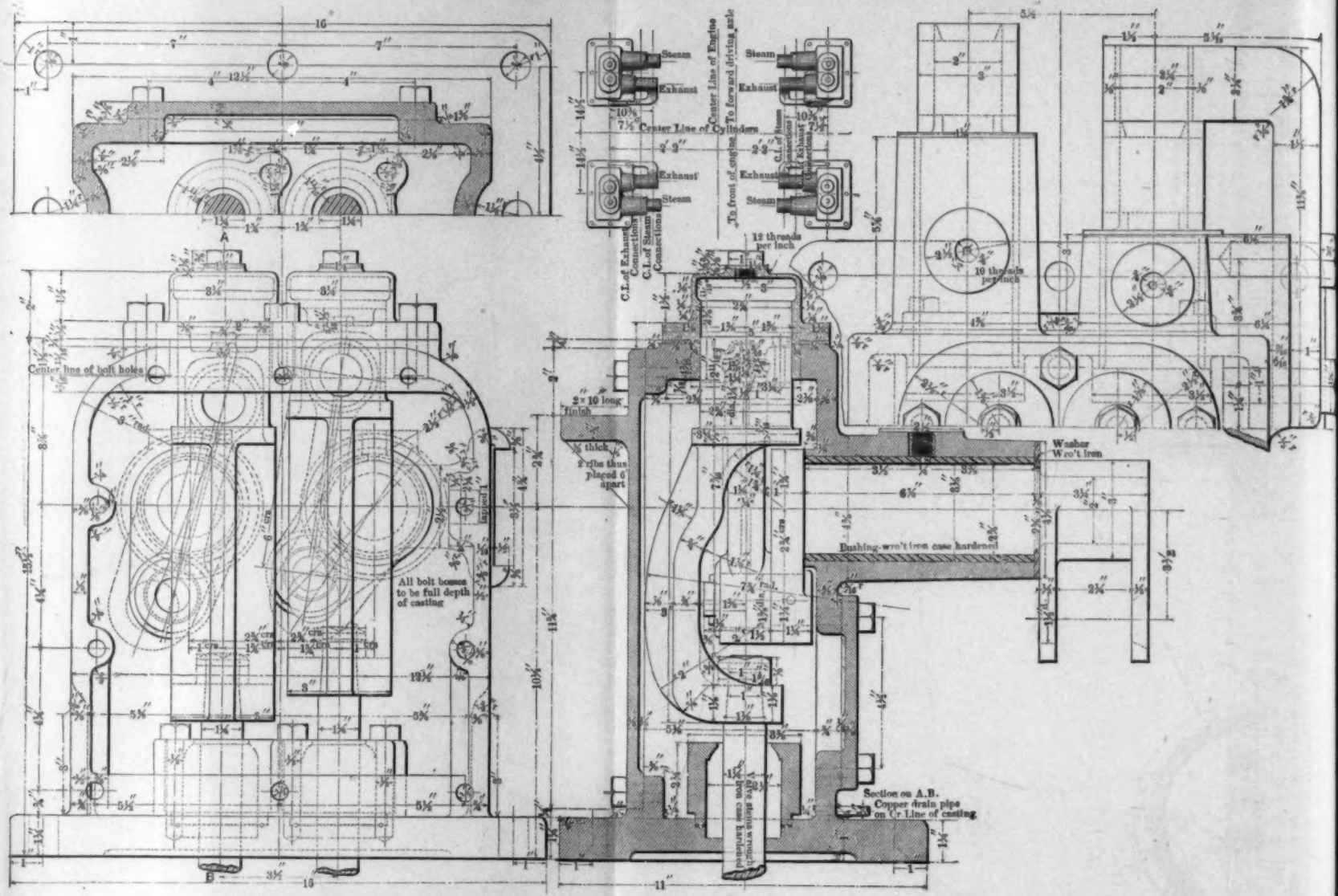
1.

2.

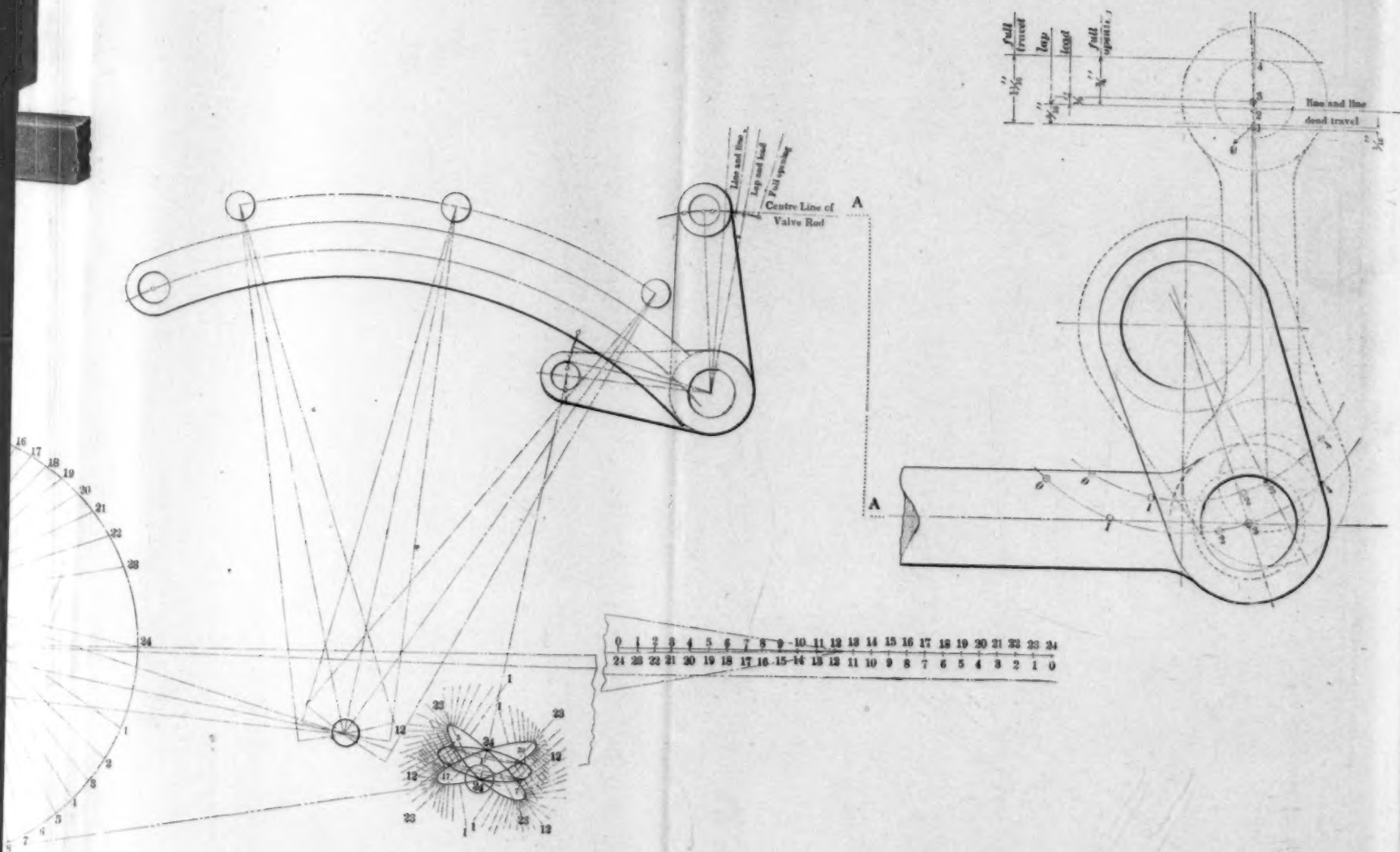
3.

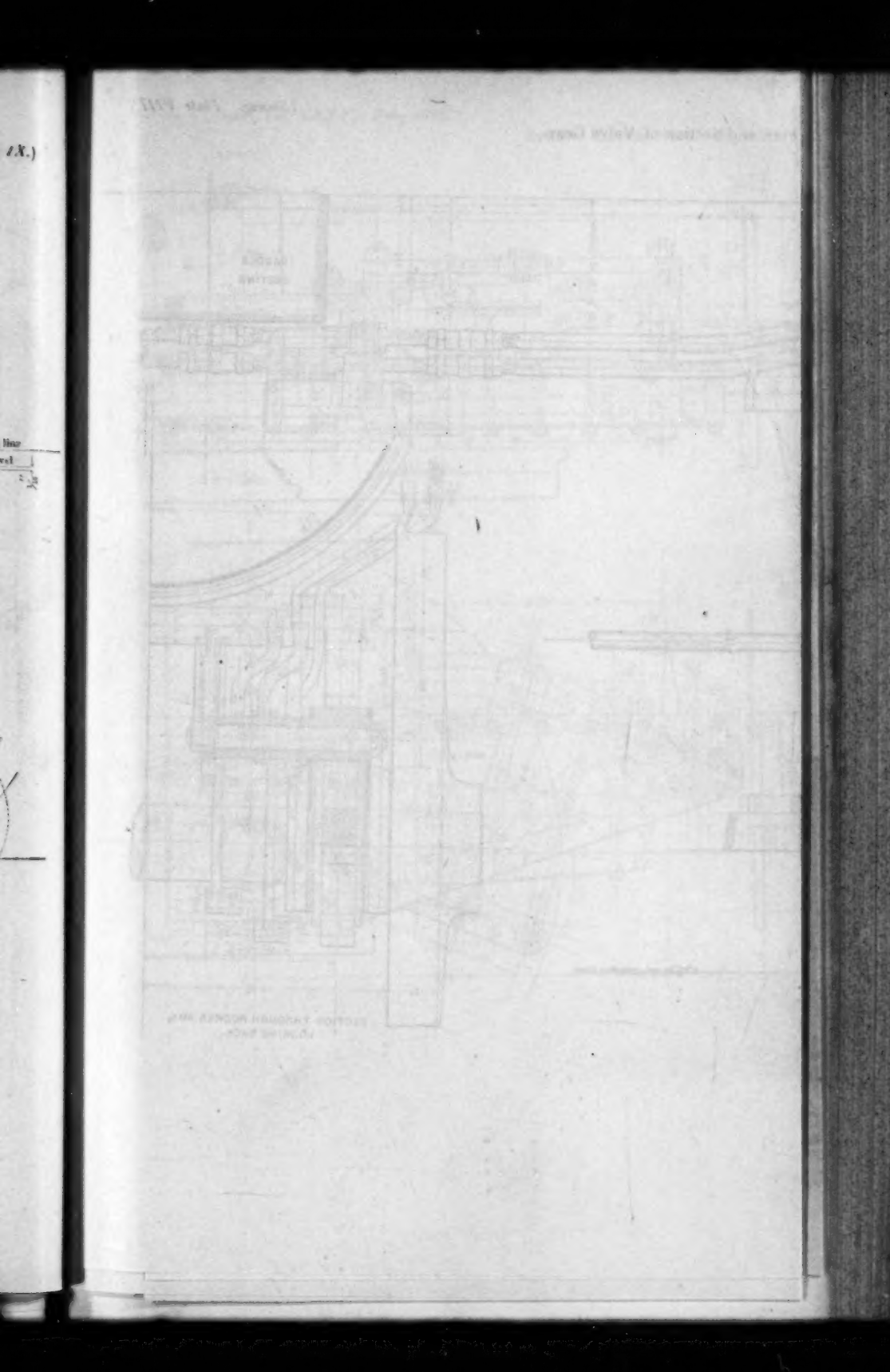


STRONG LOCOMOTIVE.—Section of Rocker-Box for Valve Gear.

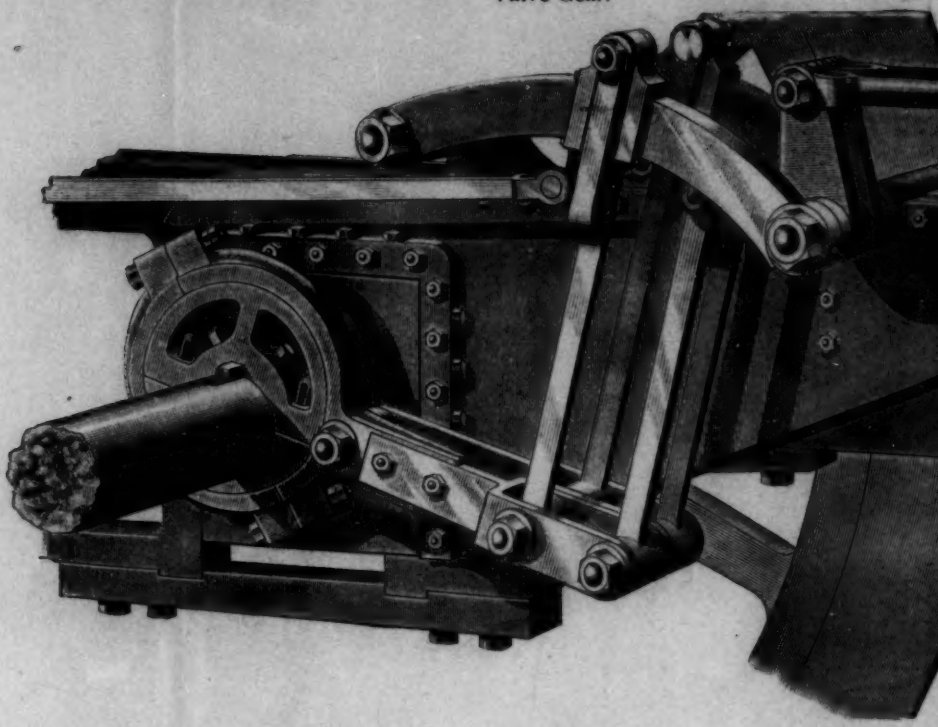

Steam
Exhaust
Center Line of Cylinders
To front of engine
To forward driving axle
C.L. of Exhaust Connections
C.L. of Steam Connections
12 threads per inch
10 threads per inch
Center line of bolt holes
2" x 10" long finish
thick
2" ribs thus placed 6" apart
All bolt bosses to be full depth of casting
Washer W'ro't Iron
Bushing wro't iron case hardened
Section on A.B.
Copper drain pipe on C.L. Line of casting
Cast iron bushing case hardened

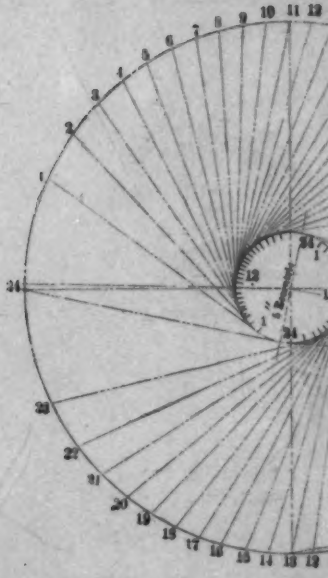
STRONG LOCOMOTIVE.—Diagram of Valve Gear.

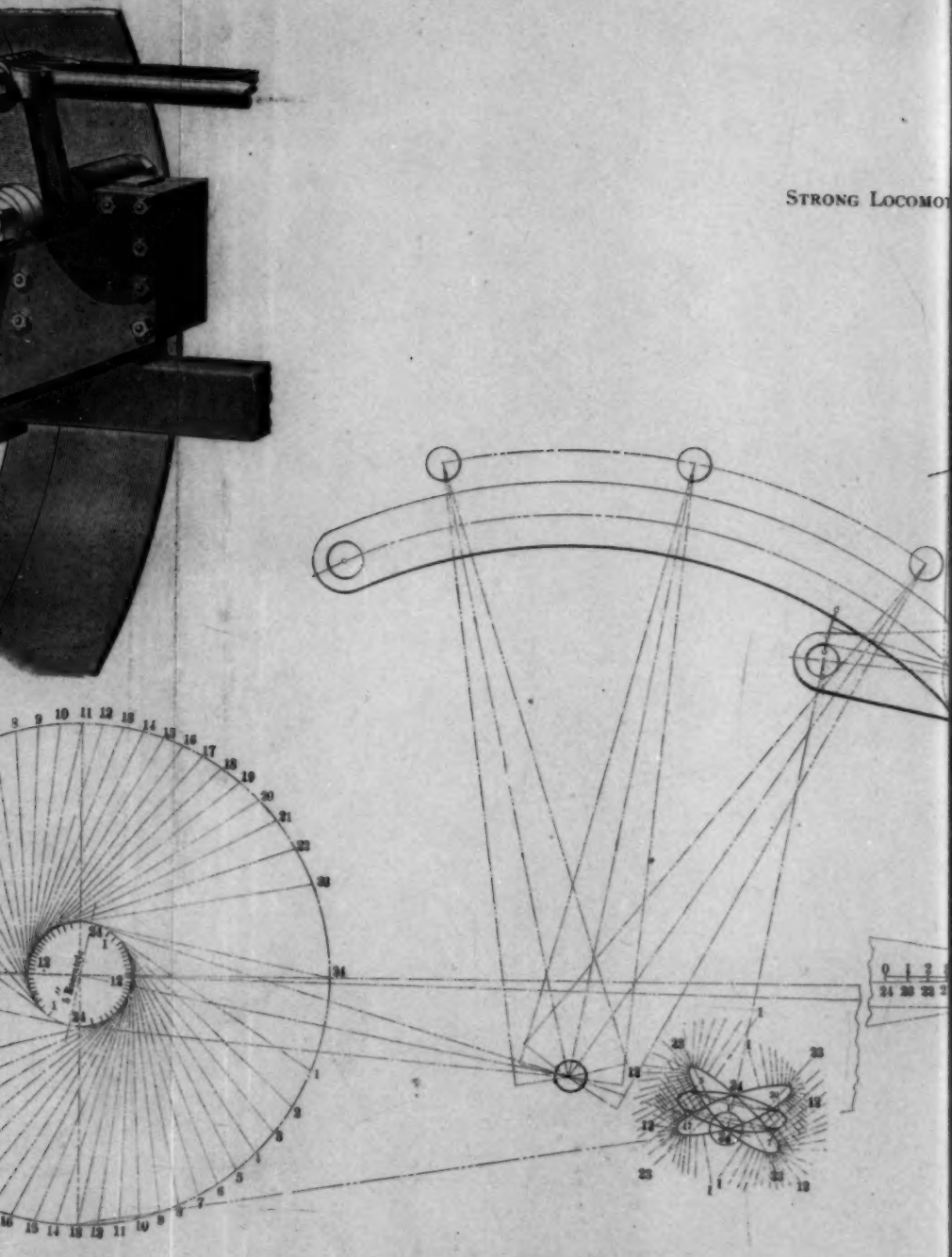

Full travel
Lap
Lead
Full opening
Line and line dead travel
Line and line
Lap and lead
Full opening
Centre Line of Valve Rod
A
A
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0



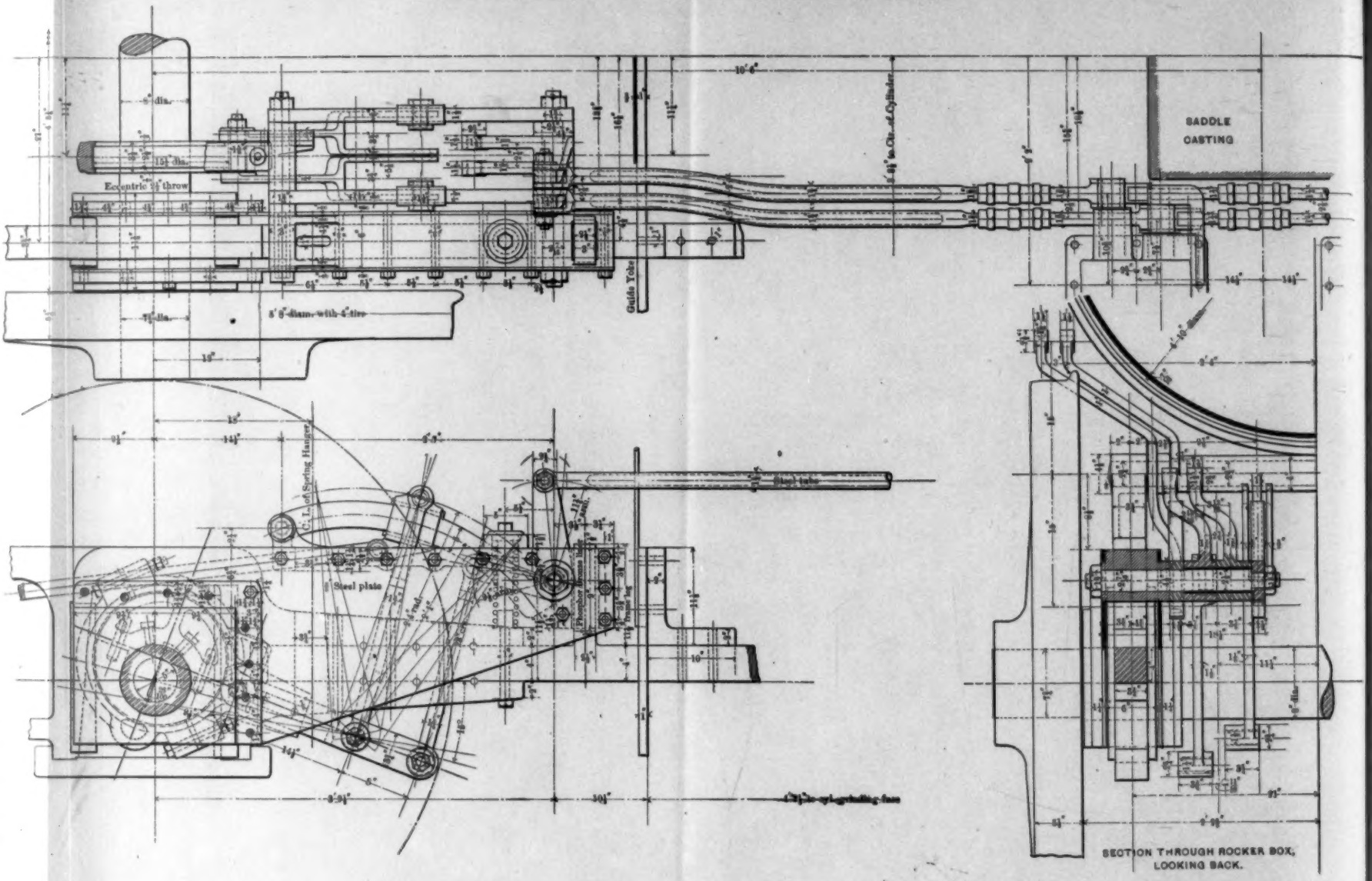
Valve Gear.

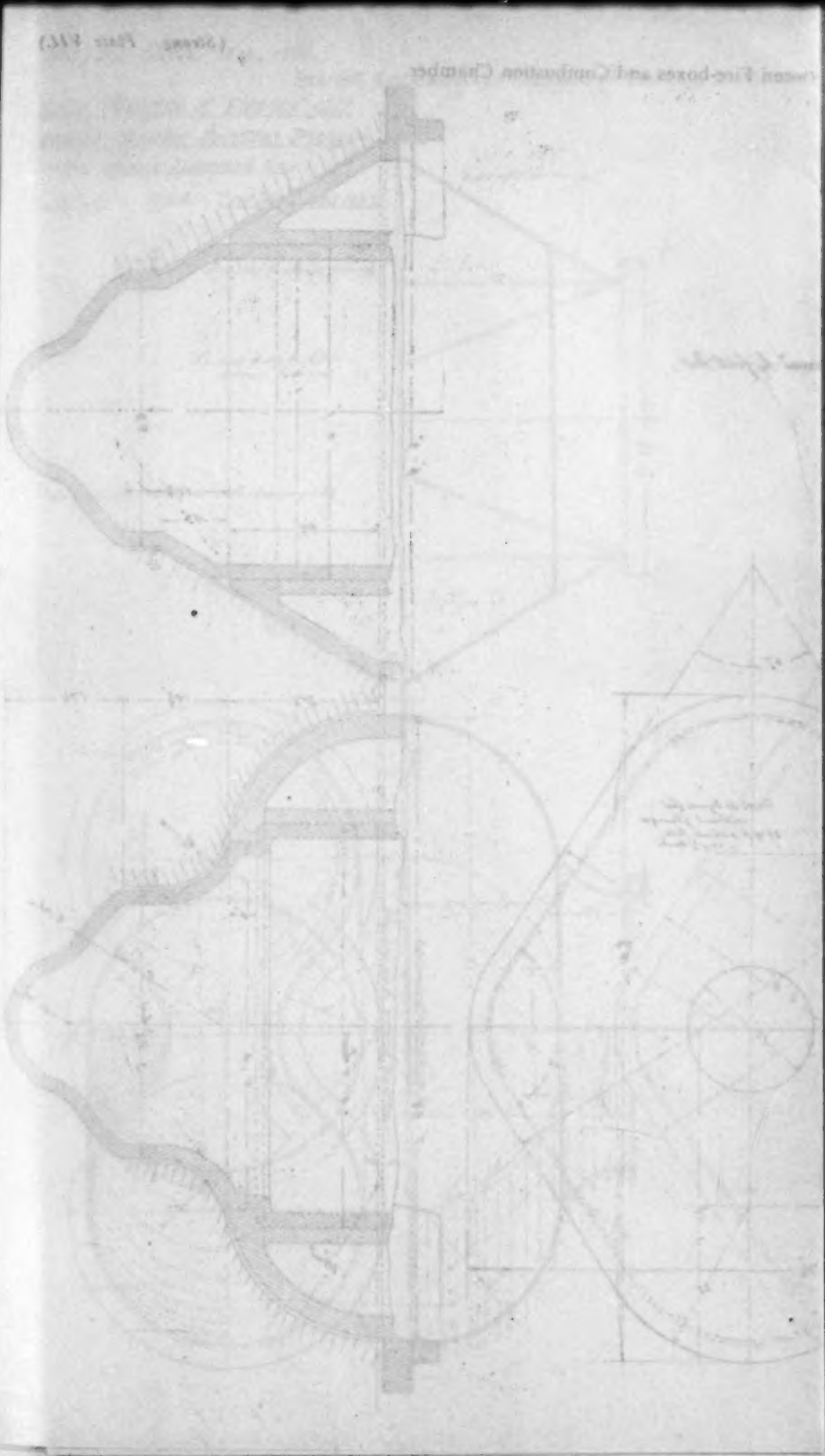




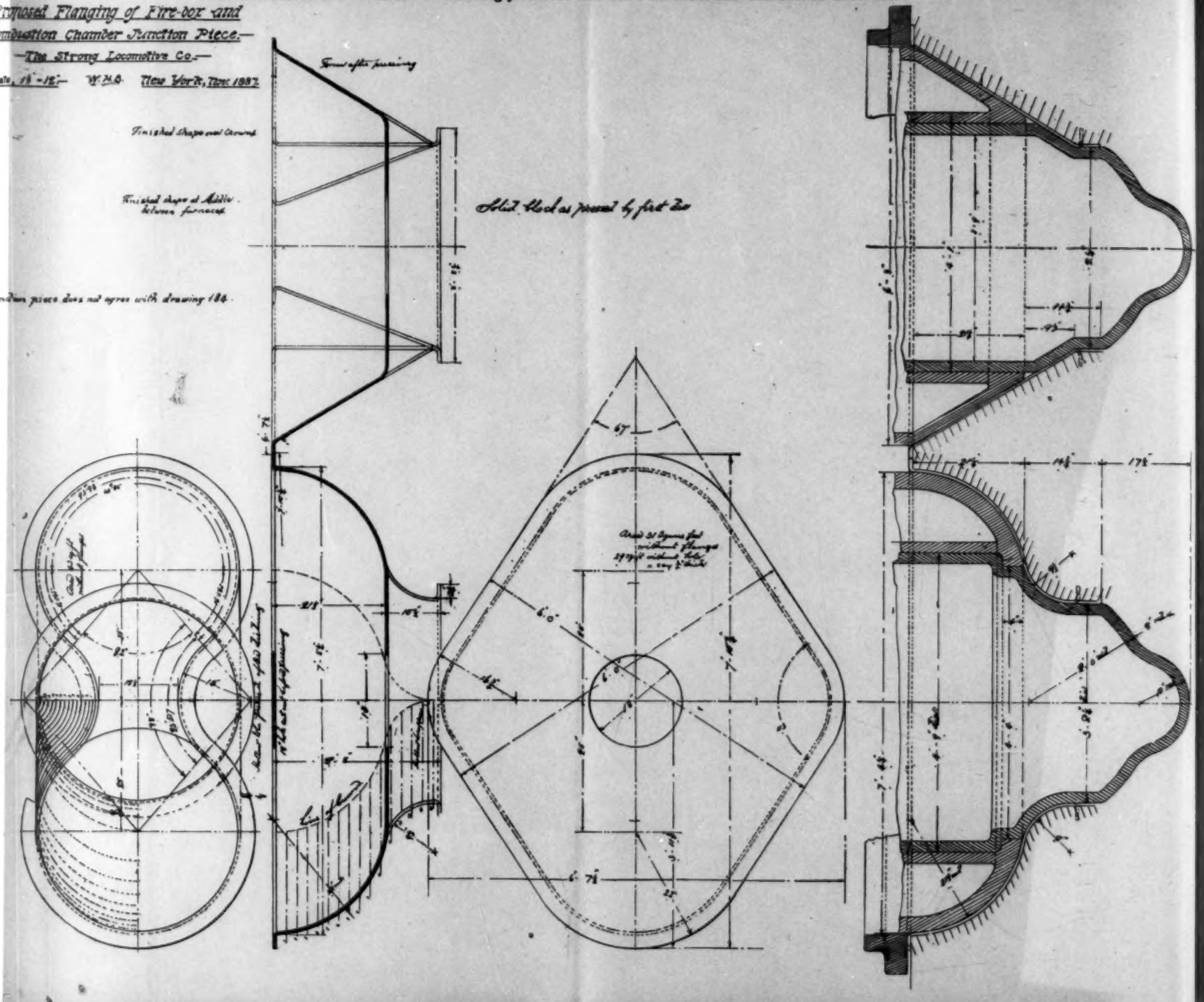


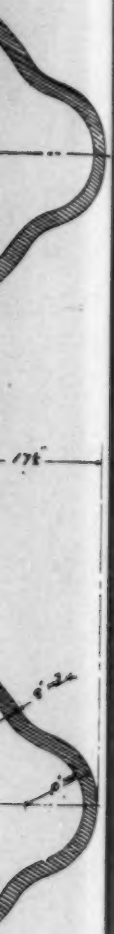
STRONG LOCOMOTIVE.—Elevation, Plan and Section of Valve Gear.





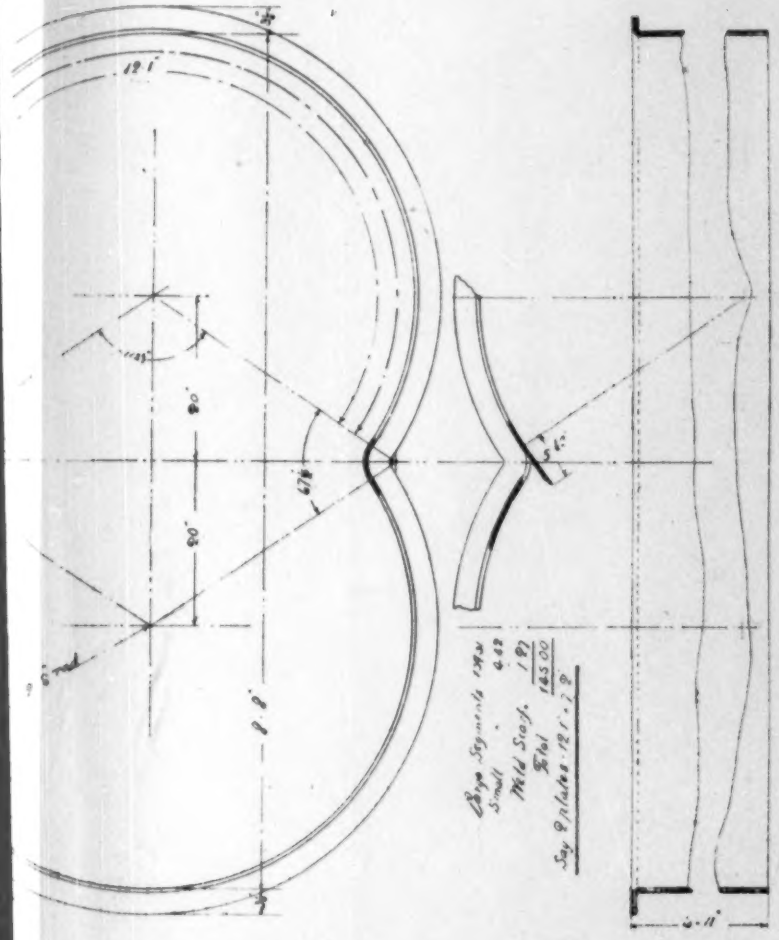
STRONG LOCOMOTIVE.—Method of Forming Junctions between Fire-boxes and Combustion Chamber.


Proposed Flanging of Fire-box and
Combustion Chamber Junction Piece.
The Strong Locomotive Co.
Scale, 1½"-12" W. H. S. New York, Nov. 1887
Finished Shape and Ground
Finished shape at Middle
Solid Head as passed by first die
Note This junction piece does not agree with drawing 184.

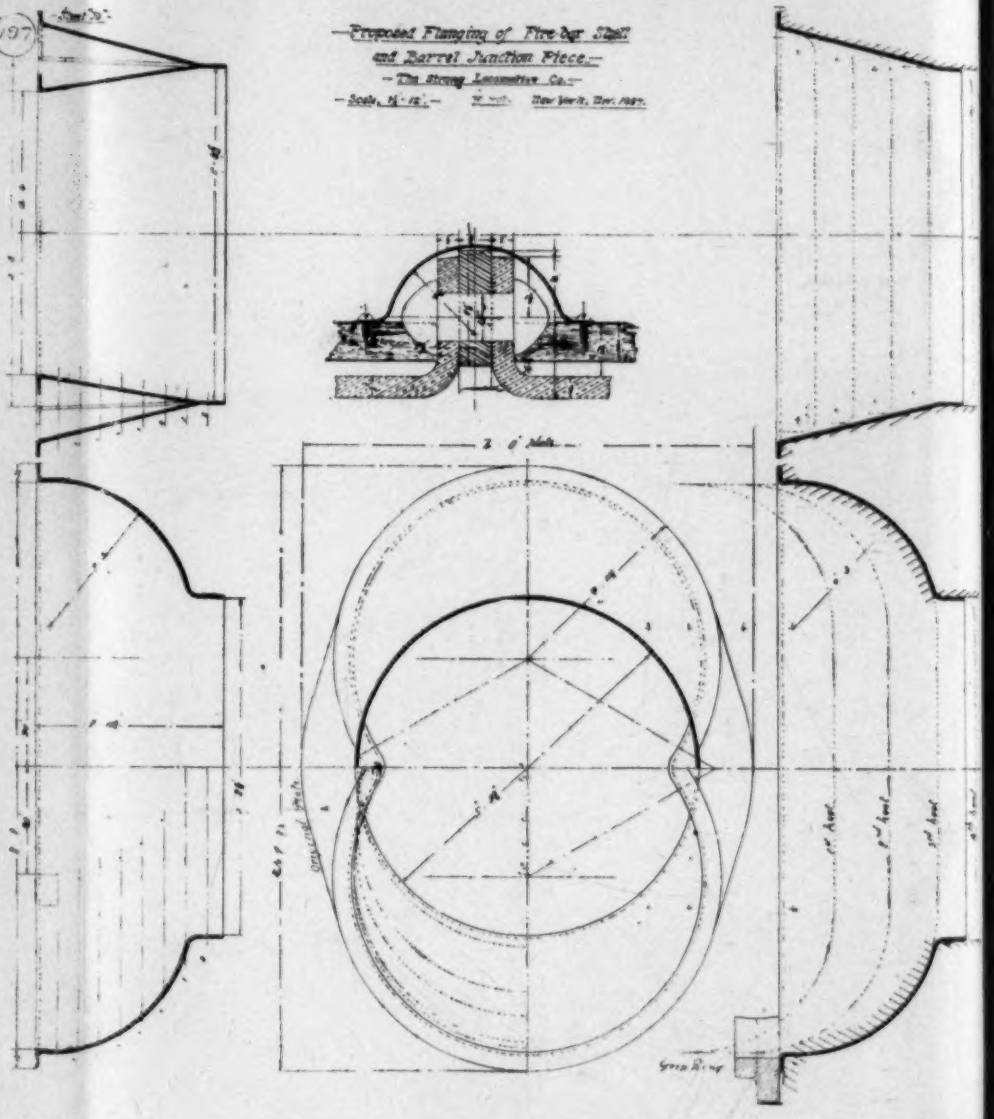


STRONG LOCOMOTIVE.

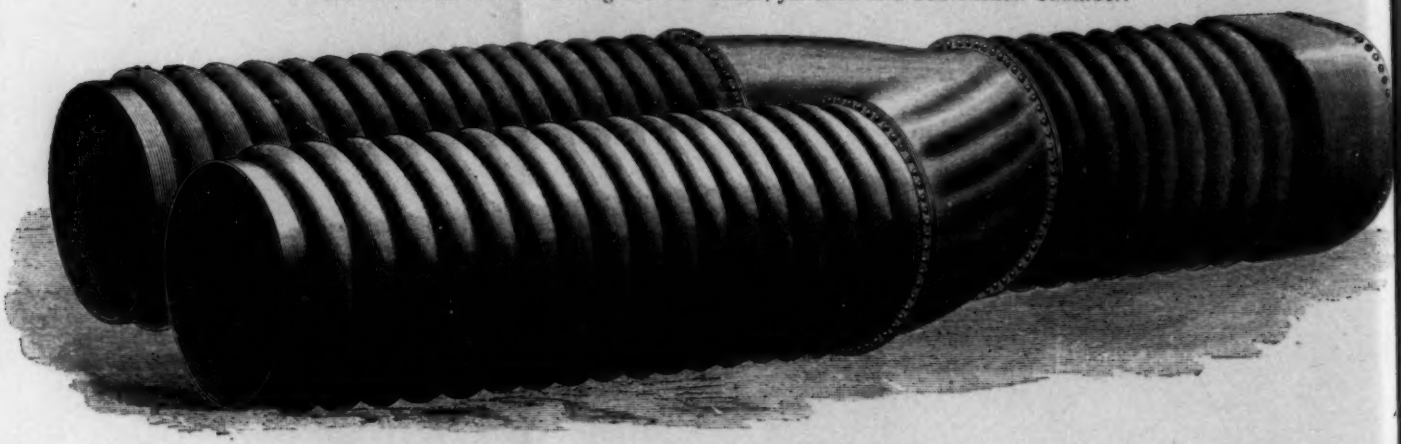
Method of Forming Outer Double Shell.



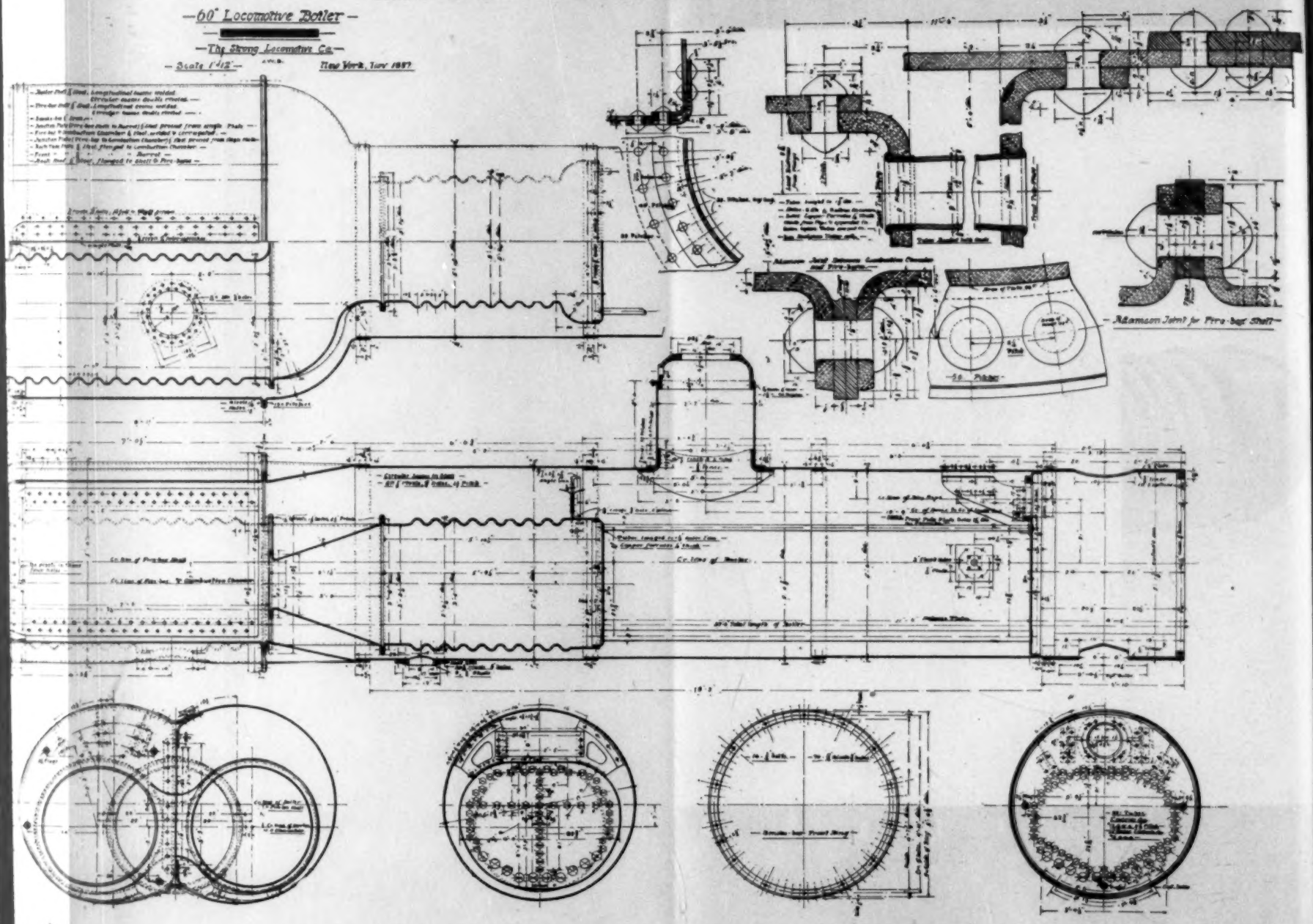
Method of Forming Junction between Outer Double Shell and Barrel.

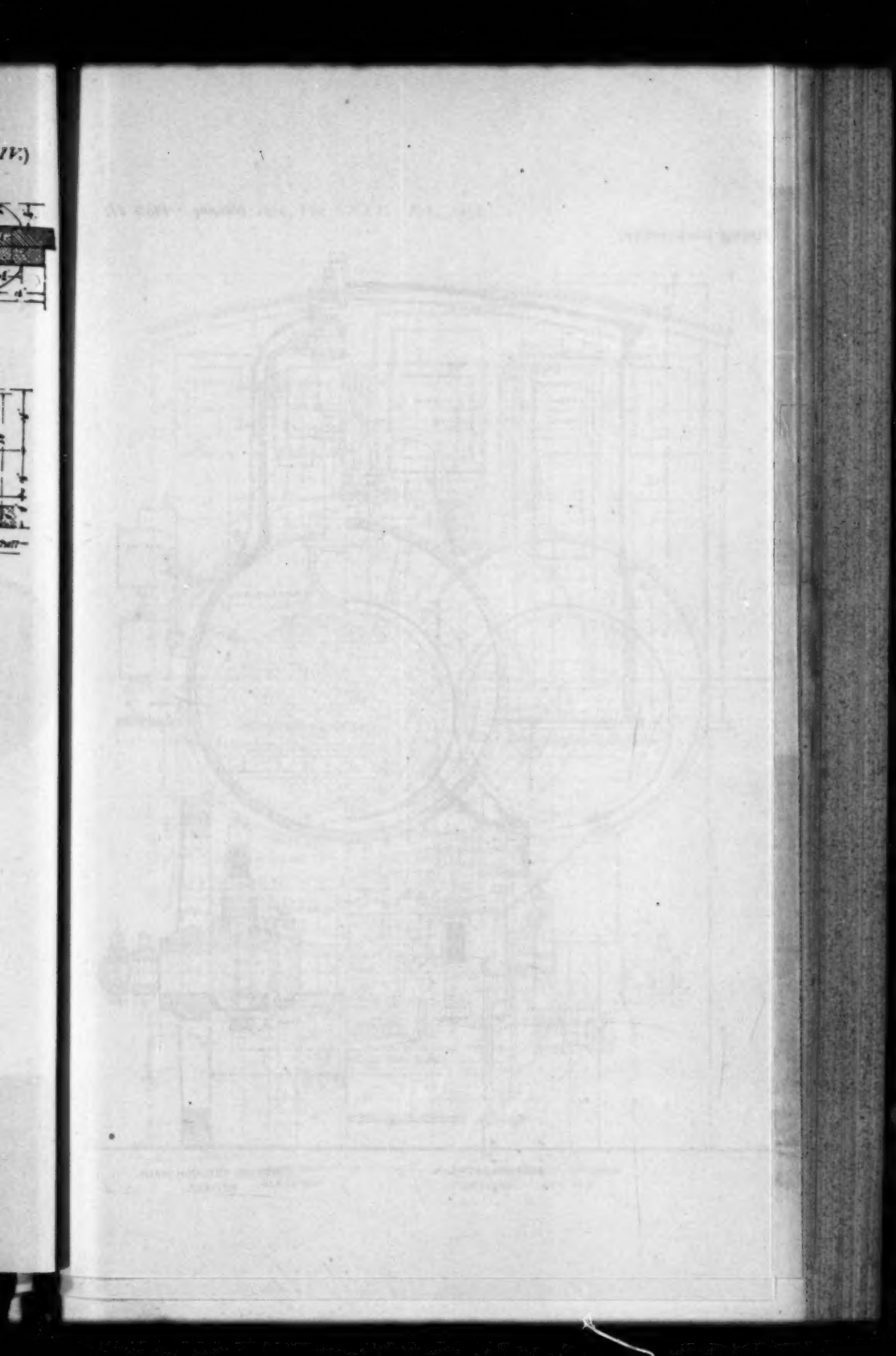


STRONG LOCOMOTIVE.—Corrugated Fire-boxes, Junction and Combustion Chamber.

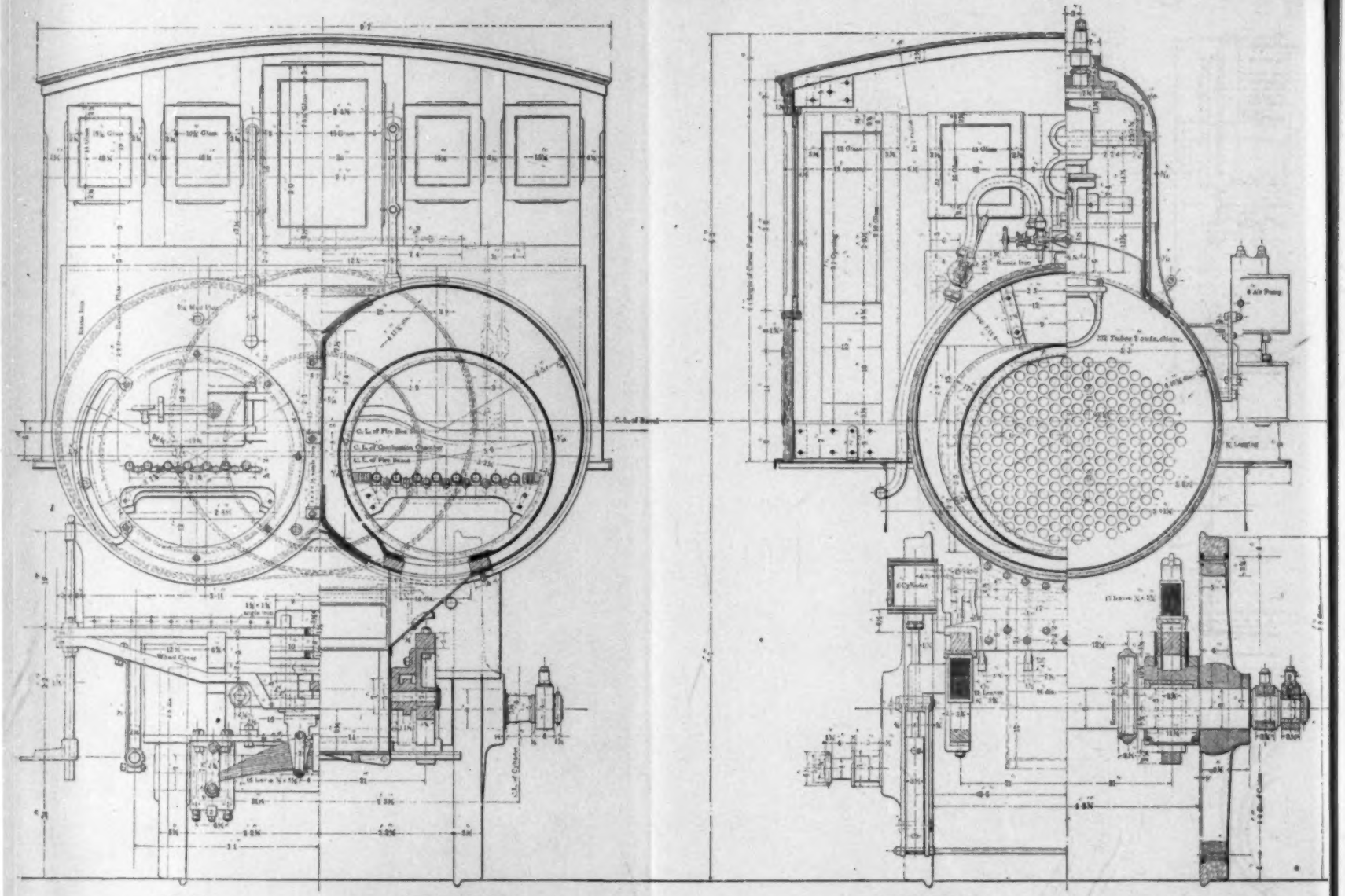


STRONG LOCOMOTIVE.—Section, Plan, Elevation and Details of Boiler.





Sections of Strong Locomotive.

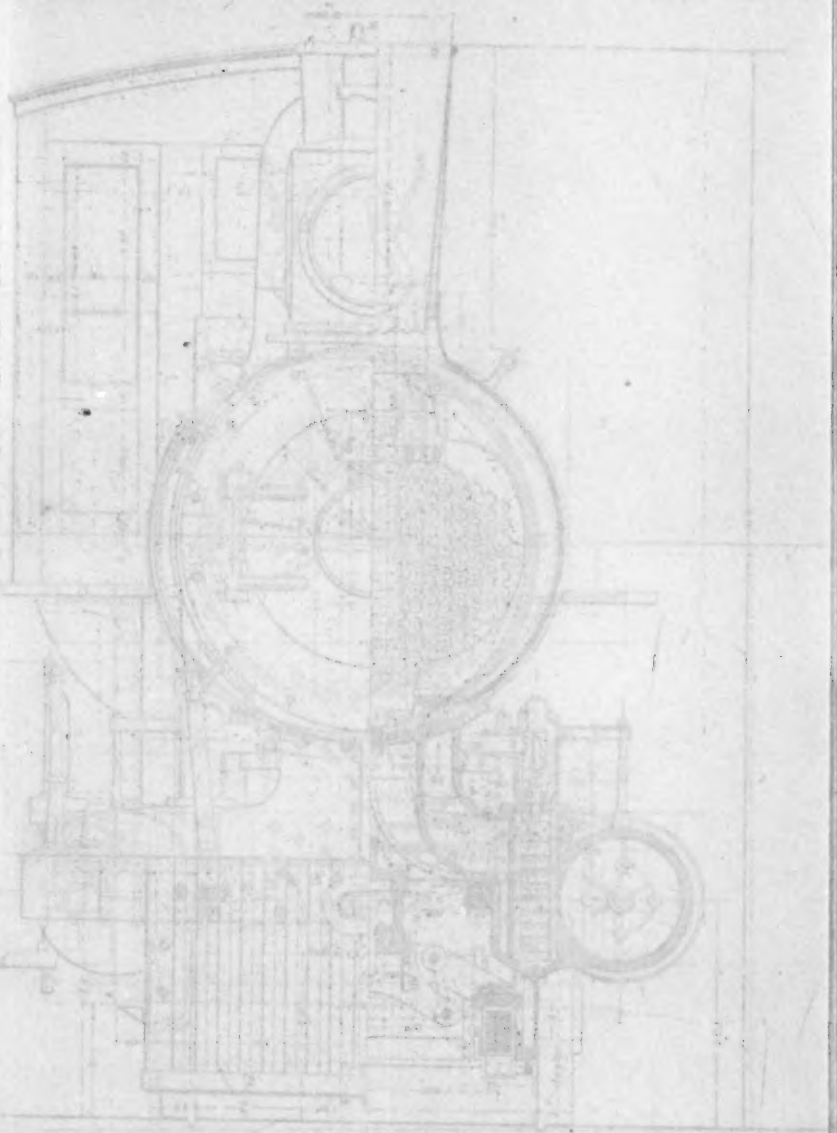


BACK END ELEVATION.

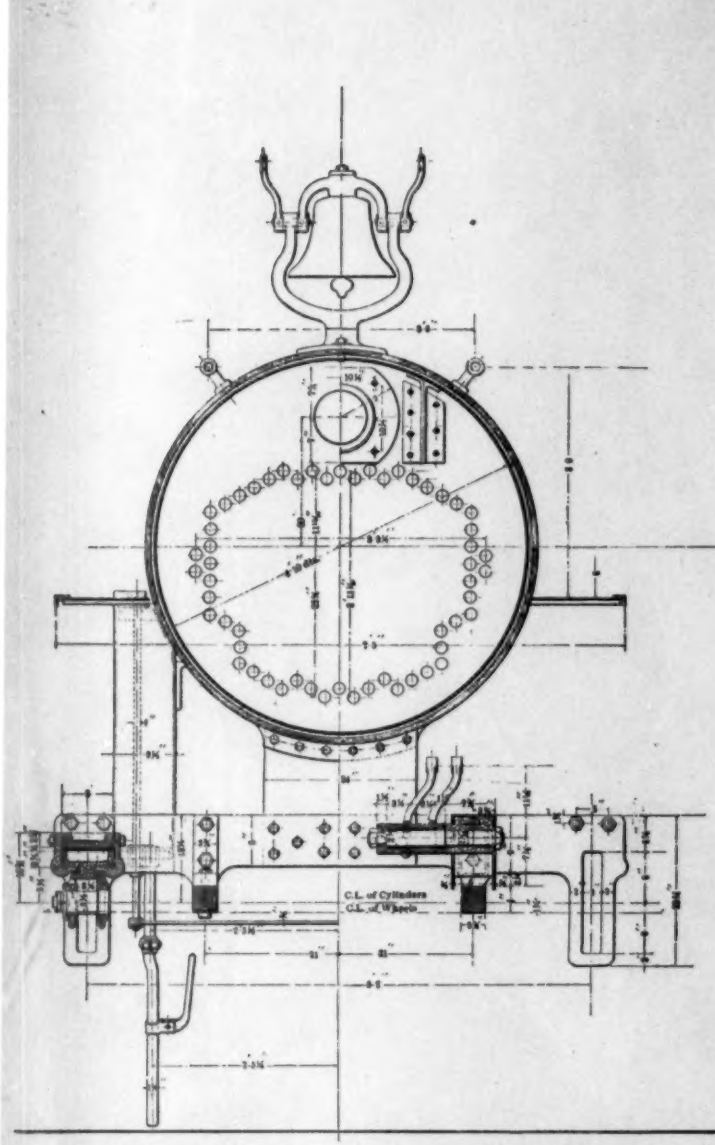
SECTION THROUGH ASH PAN.

SECTION BETWEEN DRIVERS.

SECTION THROUGH MAIN DRIVERS.

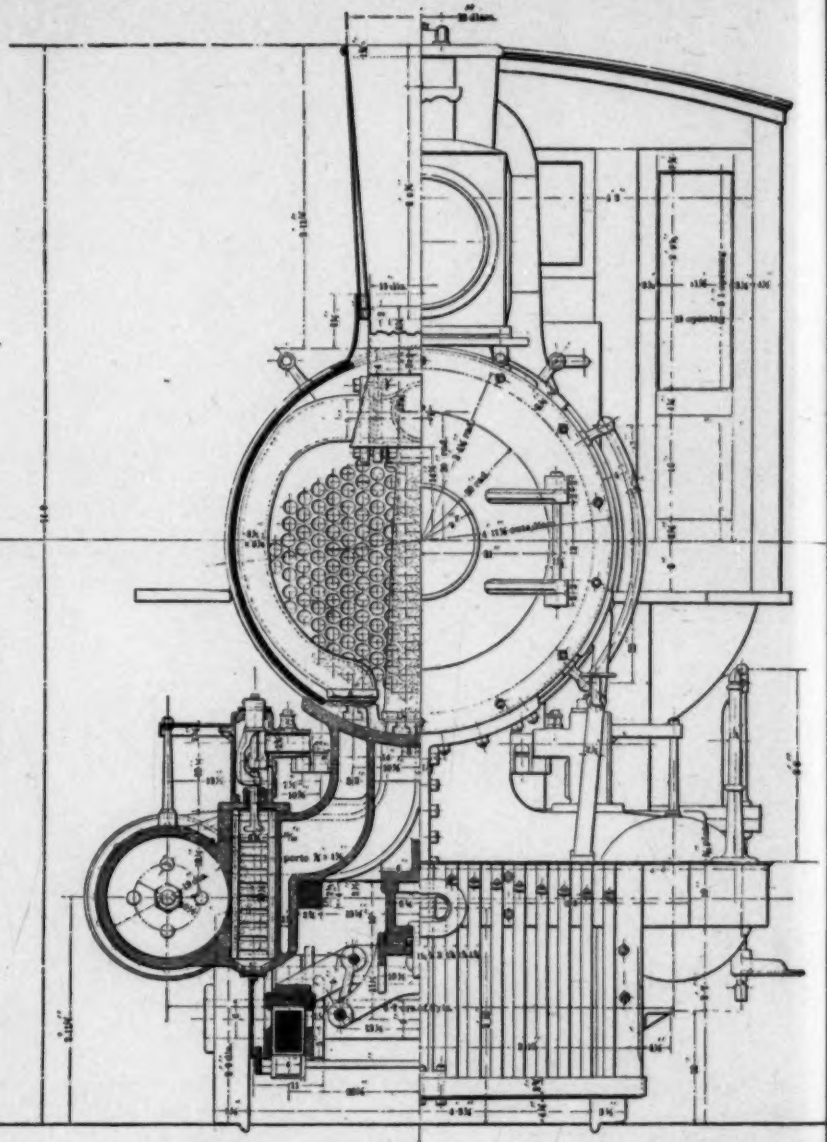


Sections of Strong Locomotive.



SECTION FRONT OF GUIDE YOKE, LOOKING BACK.

SECTION THROUGH ROCKER BOX, LOOKING FORWARD.



SECTION THROUGH CENTRE OF TRUCK AND FRONT INLET VALVE OF CYLINDER.

FRONT END ELEVATION.